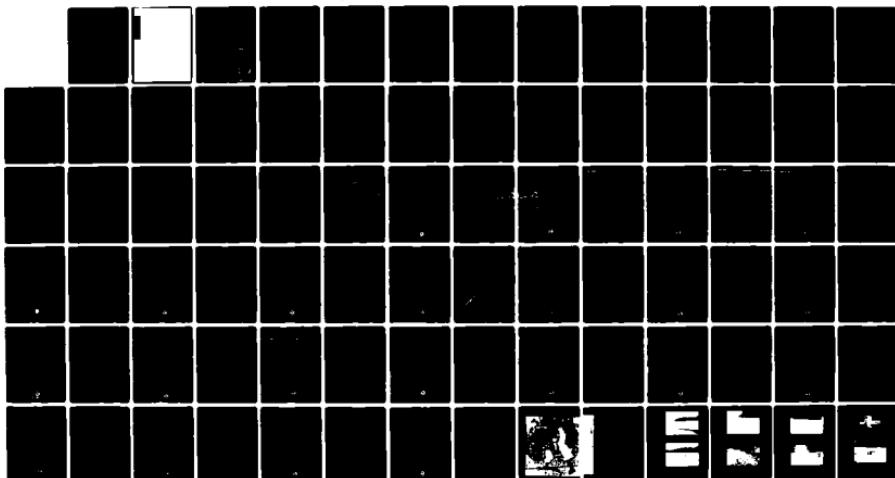


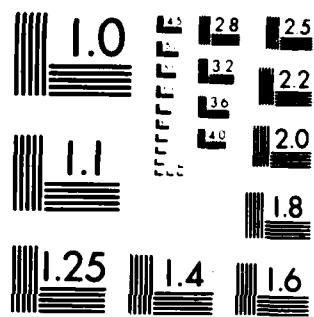
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SALT CREEK AND TRIBUTARIES, NEBRASKA
SITE NO. 13
TWIN LAKES DAM AND RESERVOIR

EMBANKMENT CRITERIA AND PERFORMANCE REPORT

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**SALT CREEK AND TRIBUTARIES, NEBRASKA
SITE NO. 13
TWIN LAKES DAM AND RESERVOIR
EMBANKMENT CRITERIA AND PERFORMANCE REPORT**

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SALT CREEK AND TRIBUTARIES, NEBRASKA
SITE NO. 13
TWIN LAKES DAM AND RESERVOIR
EMBANKMENT CRITERIA AND PERFORMANCE REPORT

PERTINENT DATA

1. AUTHORIZATION: By Public Law 500, 85th Congress, commonly referred to as the "Flood Control Act of 1958," authority was granted to construct flood control projects on Salt Creek and Tributaries, Nebraska, essentially in accordance with the report of the Chief of Engineers contained in House Document 396, 84th Congress, 2d Session. Site 13 is one of the features of the authorized project, which includes a total of 10 dams.
2. LOCAL COOPERATION: Assurances of local cooperation have been furnished by the Salt Valley Watershed District, and the State of Nebraska Game and Parks Commission.
3. LOCATION: Twin Lakes Dam, Site 13, is located in Seward County in the southeastern part of the State of Nebraska. It is located on a tributary of the South Branch of Middle Creek, which is a tributary of Salt Creek. Twin Lakes Dam is approximately 12 miles west of Lincoln, Nebraska. See Project Location Map, Plate No. A-1.
4. DRAINAGE AREA: The dam was designed to control 8.52 inches of runoff over the drainage area of 11.0 square miles.

5. RESERVOIR DATA:

<u>Zone</u>	<u>Elev. Top of Zone (Ft., m.s.l.)</u>	<u>Gross Storage Capacity (Acre-Feet)</u>		<u>Surface Area (Acres)</u>
		<u>Initial</u>	<u>100-Year</u>	
Maximum Pool (Probable Max. Flood)	1361.6	11,750	9,730	640
Full Flood Control Pool (Reservoir Design Flood - Spillway Crest El.)	1355.0	8,000	5,980	505
Normal Operating Pool (Permanent Pool - Low level outlet El.)	1341.0	2,850	1,100	270
Sediment Storage Capacity	--	2,020	--	270

6. ELEVATIONS:

	<u>Feet, M.S.L.</u>
Top of Dam (East & West Embankment)	1364.0
Spillway Crest	1355.0
Maximum Surcharge, (Spillway Design Flood)	1361.6
Full Pool	1355.0
Top of Normal Operating Pool	1341.0

7. DAM: (East & West Embankment)

Type (Both)	Homogeneous Rolled Fill, with pervious drain
Maximum Height Above Streambed	East = 55 Ft., West = 45 Ft.
Height Above Valley Floor	East = 49 Ft., West = 33 Ft.
Crest Width (Both)	15 Feet
Crest Length, Approx.	East = 2,050 Ft., West = 1,550 Ft.
Compacted Fill Quantity	East = 469,000 CY, West = 141,000 CY

8. CONNECTING CHANNEL:

Type	Uncontrolled Grassed Earth Channel
West Reservoir End Elevation	1342.0 m.s.l.
East Reservoir End Elevation	1338.0 m.s.l.
Bottom Width	Flared 80 to 65 Feet
Total Length, Average	1,450 Feet

9. EMERGENCY SPILLWAY:

Type	Uncontrolled Grassed Earth Channel
Crest Elevation	1355 m.s.l.
Length of Crest	200 Feet
Bottom Width	600 Feet
Total Length, Average	600 Feet

10. OUTLET WORKS:

Type Inlet	Concrete Drop Inlet
Low Level Gated Opening El.	1333.0 m.s.l.
Gate Size and Type	1-3.5' x 4.5' Slide w/Hand Operated Lift
Permanent Pool Outlet El.	1341.0 m.s.l.
No. Perm. Pool Openings and Size	2-2' x 5.25'
Conduit Type, Size and Length	1-42" Ø Concrete Lined CMP x 335' Long
Seepage Control	3 - Seepage Diaphragms
Invert Elevation at Intake	1318.0 m.s.l.
Invert Elevation at Outlet End	1307.0 m.s.l.
Stilling Basin	None

11. DOWNSTREAM CHANNEL:

Capacity, Max.	3200 c.f.s.
Width, Min.	10 Feet
Length, Approx.	300 Feet

12. DOWNSTREAM DISCHARGE: The maximum discharge downstream from the reservoir is 174 c.f.s. for the Reservoir Design Flood (maximum pool elevation 1355.0 m.s.l.) which is well within the bankfull capacity of 3,200 c.f.s. In the event of a probable maximum flood occurrence (maximum pool elevation 1361.6 feet m.s.l.), the maximum outflow would be 24,300 c.f.s. and would exceed the downstream capacity for a period of several days.

SALT CREEK AND TRIBUTARIES, NEBRASKA
SITE NO. 13
TWIN LAKES DAM AND RESERVOIR
EMBANKMENT CRITERIA AND PERFORMANCE REPORT

1. INTRODUCTION.

1.1 Purpose of Report. This report provides a summary record of significant design, construction, and operational data on Twin Lakes Dam for use by engineers to familiarize themselves with the project, reevaluate the embankment when unsatisfactory performance occurs, and provide guidance for designing comparable future projects. It was prepared in accordance with MRD-R 1110-1-8, subject: "Construction Foundation Reports and Embankment Criteria and Performance Reports," dated 27 February 1978 and ER 1110-2-1901, subject: "Embankment Criteria and Performance Reports," dated 1 August 1972.

1.2 Authorization and Purpose of Project. Project authorization was provided by Public Law 85-500, 85th Congress, commonly referred to as the "Flood Control Act of 1958." Authority was granted to construct a flood control project on Salt Creek and Tributaries, Nebraska, essentially in accordance with the report of the Chief of Engineers contained in House Document 396, 84th Congress, 2nd Session. Twin Lakes Dam is one of the features of the authorized project. The dam was constructed as part of a system of 10 dams and reservoirs on the tributaries of Salt Creek above the City of Lincoln, Nebraska, for flood control, fish and wildlife conservation and recreation. The permanent pool is maintained and operated for fish and wildlife conservation and recreation by the State of Nebraska Game and Parks Commission for public use.

1.3 Location and Description of Project. Twin Lakes Dam is located in Seward County in the southeastern part of the state approximately 12 miles west of Lincoln. The project is on the South Branch of Middle Creek which is a tributary of Salt Creek. The project consists of: (1) two rolled earthfill

embankments (the east having a maximum height of 49 feet above the valley floor and a crest length of 2,050 feet; the west embankment has a maximum height of 33 feet and a crest length of 1,550 feet); (2) an uncontrolled grassed earth channel spillway between the two embankments having a width of about 600 feet and a length of 600 feet; (3) an outlet works near the left abutment of the east embankment consisting of a concrete drop inlet structure and a 42-inch CMP conduit 335 feet long; (4) and a 1,450-foot long connecting channel which connects the two reservoirs to allow them to act as one for flood control storage. An aerial photograph of the project is shown on Plate B-1.

1.4 History of Project Design.

1.4.1 Survey Report. The initial recommendations for construction of a system of dams on tributaries of the Salt Creek were made in the "Survey Report on Flood Control for Salt Creek and Its Tributaries, Nebraska and Its Supplements" dated January 1953. This report formed the basis for Congressional authorization.

1.4.2 Final Design. Final design of Twin Lakes Dam (Site 13) is covered in Design Memorandum MSC-14, "Dam and Reservoir Site 13," January 1964. This report covered the design of all features pertinent to the project which included the earthfill embankments, emergency spillway, outlet works, and necessary bridge, road and utility alterations.

1.5 History of Construction Contracts. The Twin Lakes Dam project was constructed by contract, under the supervision of the Corps of Engineers, Omaha District. The job was advertised on 10 November 1964 and the bids were opened 8 December 1964. Brandt Construction Incorporated of Lincoln, Nebraska was awarded the contract (Contract No. DA 65-98) on 15 December 1964 for \$231,588.25. Construction was started on 29 December 1964 and completed 30 November 1965. No modifications were made to the contract.

2. GEOLOGY. The Salt Creek drainage basin is located primarily in Lancaster County in eastern Nebraska and lies entirely within the Dissected

Till Plains Section of the Central Lowlands Physiographic Province. Pleistocene deposits of glacial, interglacial and eolian origin overlie bedrock, which varies from relatively shallow depths to a maximum depth of over 200 feet. Bedrock under the greater portion of the basin is the Dakota Group sandstone and shales of Cretaceous age, with some Permian limestone and shales in the southeastern portion of the basin and Pennsylvanian limestone and shales in the northeastern portion of Lancaster County. In this general area a typical section of the Pleistocene deposits in descending order are as follows: Peorian Loess Formation, Loveland (loess-clay) Formation, Kansan Glacial Drift, Aftonian (interglacial) Formation, and the Nebraskan Glacial Drift. In general, the Salt Creek basin is an eroded and dissected till plain which was covered by two eolian deposits, the Loveland (loess-clay) Formation and the Peorian Loess Formation. Post-Loveland erosion removed most of the Loveland and the remaining Loveland was subsequently covered by the younger Peorian Loess. In many places, especially in the western part of the basin, all the loess, both the Loveland and Peorian, was removed by erosion exposing the underlying glacial drift. In a few local areas, notably in the eastern part of Seward County, southcentral and northeastern part of Lancaster County, and southeastern part of Saunders County, all of the Pleistocene deposits have been removed by erosion exposing the underlying bedrock.

3. FOUNDATION INVESTIGATION.

3.1 Subsurface Explorations. A total of 27 disturbed borings were drilled at the Twin Lakes Dam project during design phases in 1963 and 1964: seven at the west embankment site; eight at the east embankment site; eleven at the connecting channel, spillway, west and middle borrow areas; and one in the east borrow area located in the left abutment of the east embankment. Most of the holes were drilled with a star churn drill using 6- and 4-inch drive barrels. Additionally, four hand-auger holes were drilled just prior to construction to delineate foundation materials in the west embankment left abutment and the upstream borrow area near the east embankment left abutment.

Disturbed samples for laboratory moisture and classification tests were taken in all borings at every change in material or every 5 feet in depth whichever was less. Standard penetration tests were performed in all holes drilled along the proposed embankment centerlines. These penetration tests were taken at each significant change in material and approximately every 5 feet in depth when in the same material.

Undisturbed sampling was accomplished independent of disturbed sampling. Four holes were drilled at each embankment location within 10 feet of a previously drilled disturbed hole with a Failing rotary drill and undisturbed samples were taken at selected depths using a 6-inch Dennison barrel. Plan locations of all borings are shown on Plates A-3 and A-4. Logs of borings are shown on Plates A-11 through A-13.

3.2 Foundation Conditions.

3.2.1 Embankments. Both the east and west embankments are founded on clays of recent alluvium and Kansan glacial drift. The alluvial materials generally occupy the major part of the valley sections while the glacial drift materials occupy the valley walls (abutments). The alluvial materials are soft to stiff and moist to wet. The glacial drift materials are generally stiff to very stiff and moist. The predominance of the foundation materials classify as lean and sandy clay (CL) with intermediate layers and pockets of fat clay (CH), silty sand (SM), clayey sand (SC) and sandy silt (ML). The maximum thickness of alluvial materials was about 41 feet under the west embankment and 52 feet under the east embankment. During drilling in 1963, ground water levels were found to be about 6 to 9 feet below the ground surface in the valley alluvium. The water level in the glacial drift abutments varied considerably.

3.2.2 Spillway, Connecting Channel and Borrow Area. The predominance of the material in these areas is lean and sandy clays (CL), with lesser amounts of fat clay (CH), silty sand (SM) and clayey sand (SC). The materials are Kansan Glacial Drift and the typical soil description is

stiff, moist and light brown. Water levels recorded in the drill holes were at approximate elevation 1334 in the spillway area, but were quite variable in the west and middle borrow areas and connecting channel.

4. FOUNDATION PREPARATION.

4.1 Foundation Preparation. The entire embankment areas and the east embankment operating pool area was first cleared of all trees and other vegetation including downed timber, brush and rubbish. The clearing limits were designated to be 10 feet outside of areas where fill was to be placed and within the conservation pool limits of the east reservoir. After clearing, the foundation within the area where fill was to be placed was stripped of all vegetation, roots, sod, rubbish and other unsuitable material. After completion of the clearing and stripping, all depressions were filled and steep slopes were flattened. After filling of depressions and prior to placement of embankment, the foundation was scarified to a depth of 4 inches and compacted.

5. EMBANKMENT.

5.1 Embankment Features. Both embankments consist of relatively impervious homogeneous rolled earth fill obtained from the spillway, outlet works and borrow areas. Both embankments also have a pervious drain near the downstream toe.

5.1.1 West Embankment. The west embankment has a crest width of 15 feet, a crest length of 1,550 feet, and a height above the valley floor of 33 feet. The side slopes are symmetrical and are 1 on 2.5 for the top 5 feet, 1 on 3 for the next 14.5 feet, then 1 on 4 to the original ground. The top of the embankment is at elevation 1364.5 except that it was overbuilt up to 1 foot at the center to allow for eventual settlement. Wave protection is provided by an 18-inch thick layer of riprap overlying 6 inches of bedding, extending from elevation 1337 to 1346. The remainder of the upstream slope, the crest, and the entire downstream slope was topsoiled and seeded.

! 5.1.2 East Embankment. The east embankment has a crest width of 15 feet, a crest length of 2,050 feet, and a height above the valley floor of 49 feet. The side slopes are symmetrical and are 1 on 2.5 for the top 10 feet, 1 on 3 for the next 9 feet, then 1 on 4 to original ground. The top of the embankment is at elevation 1364 except that it was overbuilt up to 2 feet at the center to allow for eventual settlement. Wave protection for this dam is similar to that on the west embankment. The remainder of the slopes, and the crest, were topsoiled and seeded.

5.1.3 Seepage Control. An embankment seepage control drain consisting of a vertical wick of pervious material with horizontal outlets spaced at 75 feet is provided near the downstream toe of both embankments. Details of the drain are shown on plate A-8.

5.2 Embankment Materials.

5.2.1 Earthfill. Approximately 66 percent of the required excavation for the embankments (628,740 cubic yards) was obtained from the spillway, connecting channel and outlet channel excavations. The remainder was obtained from the borrow areas located in the left and right abutments of the east embankment. All of the material except that excavated from the outlet channel consists of lean and sandy clays (CL) and fat clays (CH) from the Kansan glacial drift. The material from the outlet channel consisted of alluvial clays. The borrow area locations are shown on plates A-2, A-3 and A-4. Approximately 523,950 cubic yards of fill were required to complete the embankments. Of this, about 142,700 cubic yards was for the west embankment and 381,250 cubic yards was for the east embankment. Approximately 1,920 cubic yards of pervious material, obtained from pits adjacent to the Platte River, was placed in the embankments for the pervious drains. The required gradation of this material was identical to that specified for riprap bedding material in the following paragraph.

5.2.2 Riprap and Bedding. Riprap wave protection on the embankments, spillway and around the intake structure is a quarried limestone

obtained from the Hopper Brothers quarry near South Bend, Nebraska. Specifications required the riprap to be in pieces approximately rectangular in cross section, free from thin slabby pieces having a maximum dimension more than four times the least dimension, and to be reasonably well graded between the following limits:

<u>Weight Per Stone</u>	<u>Percent of Total Weight Lighter Than or Passing</u>
320 Lbs.	100
110 Lbs.	35-60
3-Inch Screen	5-15

The bedding layers used beneath the riprap was required to be reasonably well-graded within the following limits:

<u>Sieve Size</u>	<u>Percent Passing by Weight</u>
3/4 Inch	100
No. 4	75-95
No. 16	45-70
No. 200	0-5

5.3 Embankment Placement.

5.3.1 General. Specifications required that the gradation and distribution of materials throughout the earthfill section of the dam would be such that the embankment would be free from lenses, pockets, streaks and layers of material differing substantially in texture or gradation from surrounding material.

5.3.2 Compacted Embankment Fill. The more impervious materials were to be placed toward the upstream section of the embankment and the more pervious materials were to be placed toward the downstream section of the embankment to affect a transition in permeability from upstream to downstream faces of the embankment. Specifications required that the impervious fill material be placed in approximately horizontal layers not exceeding 6 inches

in thickness after compaction. The moisture content was to range from 2 percent above optimum to 4 percent below optimum. The top of the fill was required to be crowned with a 5 percent grade so that it would have good drainage during the construction period. Before compaction, each layer of fill was required to be harrowed, if required, to break up and blend materials and to obtain uniform moisture content. If one pass of the harrow did not break up or blend the materials sufficiently, additional passes were necessary, but no more than three passes were required to be performed.

There were no specific number of passes of roller equipment required; but each layer was to be compacted to at least 95 percent of the maximum density as determined by the Standard AASHO method, T99 Method D. Portions of the fill which could not be compacted with rollers because of space restrictions, were placed in 4-inch loose lift layers and compacted with power tampers to the same degree of compaction as that obtained on other portions of the fill performed by rolling.

Compaction was accomplished by American ADC 120 sheep's-foot tamping rollers. The roller had two 5-foot diameter drums with 120 feet per drum. Each foot on the drum was 8 inches long with a bearing area of 6.25 square inches. Contact pressure was 377 p.s.i. for an empty drum and 594 p.s.i. for a drum filled with water. The roller was propelled by a Caterpillar "B" pull power unit.

5.3.3 Embankment Drain. After excavation for the drain was completed, the filter material was placed in the trenches in layers not exceeding 8 inches in thickness before compaction, saturated, and then compacted with a vibrating plate compactor.

5.3.4 Field Control Tests. Moisture-density control tests were taken by the Corps of Engineers Area Office for approximately every 1,700 cubic yards of compacted fill placed. Both nuclear and sand-cone methods were used for the determination; however, nuclear methods were used generally as a supplement to the sand-cone method.

Standard compaction tests were performed on each type of material for comparison with the in-situ moisture-density determined in the field.

At the completion of the earthfill operations the following results of field control testing had been obtained for the impervious fill materials: No tests were taken on pervious drain materials.

Field Control Test Results

Total No. of Tests	183	
	No. Outside Limits	% of Total
Total	8	4.4
Moisture	8	4.4
Density	0	-
Moisture & Density	0	-

The field control tests indicated that the majority of the fill was placed from -1.5 to +1 percent of optimum moisture.

5.3.5 Record Undisturbed Samples. Record undisturbed samples were not taken at this project.

5.3.6 Slope Protection Placement. The specifications required that the 6-inch thick bedding material be placed in a manner that would prevent segregation of particle sizes. Compaction of the layer was not required, but it was to be finished to present a reasonably even surface. The average thickness was to be within a tolerance of plus or minus 1-inch from the thickness required and measured within areas not exceeding 100 square feet.

Riprap stone was required to be placed on the bedding layer so as to produce a reasonably well graded mass of rock with a minimum of voids. A tolerance of plus or minus 4 inches from the required slope lines and grades were allowed except that either extremes of such tolerance was not to be

continuous over an area greater than 200 square feet. The riprap was to be placed to its full thickness in one operation in such a manner as to avoid displacing bedding material. The desired distribution of stones throughout the mass was obtained by selective loading at the quarry site and by controlled dumping. All stone was required to be placed by either a clam, orange peel or skip box and rolling or pushing the stones into place was not permitted.

5.4 Embankment Settlement. Settlement studies were performed using the results of two consolidation tests. One of the samples was considered representative of the firm foundation material and one was representative of the soft alluvial material at both the east and west embankment sites. Pressure-void ratio curves are shown on Plate A-18.

5.4.1 West Embankment. A maximum embankment section of 33 feet in height was considered to bear on 41 feet of compressible valley alluvium. Of this compressible alluvium, a 33-foot soft layer was considered to overlay an 8-foot firm layer. Drainage for both layers was considered as single drainage. The maximum computed foundation settlement of the embankment centerline is 2.1 feet. Time-rate settlement computations indicated approximately 55 percent of the total settlement would take place up to the end of construction and 95 percent of the remaining settlement of approximately 1 foot would occur at a diminishing rate over a period of about 12 years. The embankment was overbuilt 1.0 foot for that portion of the dam in the valley to allow for the residual settlement and to insure that a minimum of at least 2 feet of freeboard above the maximum pool is maintained. The overbuild was reflected in the earthwork quantities for the embankment. A profile showing the overbuild is on Plate A-5.

5.4.2 East Embankment. A maximum embankment section of 49 feet in height was considered to bear on approximately 52 feet of valley alluvium. The alluvium consisted of a 40-foot layer of soft material and overlays a 12-foot layer of firm material. Drainage for both layers was considered as

single drainage. The maximum computed foundation settlement at the embankment centerline is 3.9 feet. Time-rate computations indicated that approximately 55 percent of the total settlement would take place up to the end of construction and 95 percent of the residual settlement of approximately 2.0 feet would occur over a period of about 14 years. The embankment was overbuilt 2.0 feet for that portion of the dam in the valley to allow for the residual settlement. The earthwork quantities for the embankment reflected the overbuild. A profile showing the overbuild is on Plate A-6.

5.4.3 Conduit. The conduit for the outlet works is located in the left abutment of the east embankment as far as possible to minimize the amount of compressible alluvium beneath the conduit and intake structure. The maximum computed settlement at the intersection of the conduit alignment and the embankment centerline was 0.97 foot. Accordingly, the camber of the conduit was set at 1.0 foot to allow for the theoretically computed settlement.

5.5 Embankment Stability.

5.5.1 Shear Tests.

5.5.1.1 Remolded Testing. Remolded tests were not performed on the proposed embankment materials as the type of material, liquid limits, plastic limits and moisture contents were generally similar to the material used for the construction of the embankments at Sites 11 and 12 on the Salt Creek. The shear values used for the embankment strengths on this site were considered to be conservative in relation to the actual strengths obtained on remolded samples from Sites 11 and 12.

5.5.1.2 Undisturbed Testing. Undisturbed sample shear tests consisted of three unconsolidated-undrained (Q) triaxials; three consolidated-undrained (R) triaxials; and three direct shear tests. All tests generally consisted of three specimens. The triaxial specimens were 1.4 and 2.8 inches in diameter and the direct shear specimens were 3x3x0.5 inches. Confining pressures for the triaxials and normal loads for the

direct shear tests were 1, 3 and 5 tons per square foot. The tests were considered to be representative of the foundation conditions beneath both embankments which included: (1) the soil above the water table, (2) a soft layer of material below the water table, and (3) a firm material below the soft material.

The shear tests, test summaries and adopted strengths are shown on Plates A-16 and A-17. The strengths for both the east and west embankments and their foundations were assumed to be identical except for the soft layer of material below the water table. For this layer, the shear strength at the east site was adopted slightly higher than the west site, as shown on the plates.

5.5.2 Stability Analyses. Stability analyses were performed on the upstream and downstream slopes of the maximum embankment sections for each embankment. The analyses consisted of four cases which simulate conditions of stress during the life of the structure: (1) end of construction; (2) steady seepage; (3) partial pool, and (4) sudden drawdown. The end of construction analyses, which was one of the more critical cases, is illustrated on Plate A-18. All analyses were hand computed using the circular arc methods outlined in Engineering Manual 1110-2-1902, 27 December 1960.

5.5.2.1 Adopted Strengths. The adopted strengths plus the foundation layer thicknesses and embankment heights used in the stability analyses are shown below:

<u>Material</u>	<u>Height/ Thickness (Ft.)</u>	<u>"Q" Strength</u>		<u>"R" Strength</u>		<u>"S" Strength</u>	
		<u>Tan ϕ</u>	<u>TSF</u>	<u>Tan ϕ</u>	<u>TSF</u>	<u>Tan ϕ</u>	<u>TSF</u>
West Embankment	33	0.15	0.80	0.23	0.35	0.50	0.0
Fdn Stratum "A"	6	0.18	0.60	0.27	0.48	0.57	0.0
Fdn Stratum "B"	27	0.0	0.31	0.21	0.10	0.61	0.0
Fdn Stratum "C"	8	0.08	0.54	0.25	0.56	0.56	0.0
East Embankment	49	0.15	0.80	0.23	0.35	0.50	0.0
Fdn Stratum "A"	9	0.18	0.60	0.27	0.48	0.57	0.0
Fdn Stratum "B"	31	0.0	0.40	0.21	0.30	0.61	0.0
Fdn Stratum "C"	12	0.08	0.54	0.25	0.56	0.56	0.0

5.5.2.2 Summary of Results. The following table summarizes the stability analyses results for the project. Plate A-18 shows typical end of construction case computations and conditions for each embankment section.

SUMMARY - STABILITY ANALYSIS FACTORS OF SAFETY

Embank- ment	End of Construction		Steady Seepage			Partial Pool		Sudden Drawdown*		
	"Q"	RQ	"R"	"S"	Avg.	RQ	"R"	RQ	"R"	RQ
West	1.57	1.3	1.47	2.18	1.82	1.5	1.53	1.5	1.34	1.0
East	1.34	1.3	1.52	1.83	1.67	1.5	1.5	1.5	1.83	1.0

Q, R, S - shear strength test type

RQ - required factor of safety

* - drawdown from max. pool to conservation pool

5.6 Seepage Control.

5.6.1 Embankment Seepage. It was assumed that seepage through the embankment would be minor due to the low permanent pool levels, short duration of flood pools and the relatively low permeability of the compacted embankment materials. However, to prevent the possibilities of saturation and sloughing of the lower downstream slopes, an internal pervious drain was constructed in the downstream section of the embankment as described previously in paragraph 5.1.3.

5.6.2 Foundation and Abutments. Seepage control provisions for the foundation were considered unnecessary due to the impervious materials of foundation.

5.7 Diversion and Closure. Diversion channels were constructed at station 7+00 for the west embankment and at station 12+00 for the east embankment. Plates A-3 and A-4 show the locations of these channels and the various plugs which the Contractor was required to place to divert flow of water from several locations to the constructed diversion channels. The diversion channels were constructed with 1V on 3H side slopes.

Prior to starting the east embankment closure operations, the Contractor was required to complete the outlet works, outlet channel, the necessary clearing and structural removals, and the embankment right and left of the closure section to a minimum elevation of 1333.0 (31.0 feet below crest elevation).

Prior to starting the west embankment closure operations, the Contractor was required to complete the spillway excavation, a pilot channel through the connecting channel area to design grade, the east embankment fill complete to a minimum elevation of 1356.0 (8 feet below crest elevation) and the west embankment either side of the closure section to a minimum elevation of 1351.0 (13.5 feet below crest elevation).

Final closure was made in September 1965.

6. OUTLET WORKS.

6.1 Description. The outlet works, located in the east embankment, consists of a concrete drop inlet structure and a 335-foot long, 42-inch CMP conduit lined with a 30-inch R.C.F. The concrete lining was added in 1980, due to deterioration of the conduit caused by corrosion. The conduit has three metal seepage control diaphragms beneath the central portion of the embankment. The drop inlet, which is founded on alluvium, has two openings at two levels, a gated opening at elevation 1333 and two permanent pool openings at elevation 1341. The low level opening is rectangular in shape, 42 inches by 54 inches, and is manually controlled by operating a slide gate from the top of the cover plate. The purpose of the gated outlet is to lower the level of the conservation pool in order to inspect the conduits, make shore-line repairs or control the fish population. The ungated openings are protected with metal pipe trash racks. The discharge end of conduit is extended on a pile trestle well past the downstream toe of the embankment. An outlet channel extends downstream from the conduit end to the original creek channel. Approximately 13,000 cubic yards of excavation was obtained

from this channel. A plan and profile of the outlet works are shown on Plate A-14. Photographs of the outlet works system both during and after construction are shown on Plates B-5 and B-6. A piezometer system to measure hydraulic and friction losses in the intake structure and discharge conduit was also installed during construction of this structure. Mountings were provided for eight pressure probes inside the outlet works conduit, each at 40 feet intervals along the spring line of the left side of the conduit. The piezometer system is now inoperative due to the relining of the conduit in 1980.

6.2 Backfill. Backfill adjacent to the outlet structure was required to be placed in 4-inch loose layers and compacted to the same density and at the same moisture content as the main embankment material. Rollers were not permitted to operate within 2 feet of the structure walls, conduit sides or conduit top. Within this restricted area, and others where rollers could not be used, the material was required to be tamped by power tampers. Backfill was not allowed to be placed on or against concrete surfaces for 10 days after concrete placement. The backfill was required to be brought up uniformly on all sides in order to avoid distortional stresses in the structures. Equipment used for backfilling varied from Air Compressor powered air tampers to gasoline powered "Barco" rams.

7. EMERGENCY SPILLWAY. The emergency spillway is a grass lined, uncontrolled, earth cut 600-foot wide channel with 1V on 3H side slopes located through a ridge between the two embankments. The crest portion of the spillway is at elevation 1355 or 9 feet below the embankment crest and is 200 feet long. The slope downstream from the crest is 0.2 percent. Approximately 88,000 cubic yards of material was obtained from the excavation. Plans and sections of the spillway are shown on Plates A-3 and A-5.

8. INSTRUMENTATION.

8.1 General. The project instrumentation consists of five open tube type piezometers; eleven embankment crest movement markers; and four movement insert markers on top of the concrete intake structure.

8.2 Piezometers. Five open tube type piezometers were installed at the project in 1976. The piezometers are a standard well point type with a 2-inch diameter galvanized pipe and a 30-inch long screen. They are surrounded by a sand-gravel sensing zone within a 4-inch diameter hole. Bentonite seals are used above the sand zone.

Three of the piezometers are located at the east embankment where two have been placed in the foundation alluvial materials and the third was placed into the backfill material adjacent to the conduit at a downstream location to check possible seepage pressures. The other two piezometers were placed in the downstream foundation materials of the west embankment near the old channel. Plate A-19 shows locations and installation details. Observations of the piezometers since installation have indicated no unusual conditions. The observations are plotted with pool elevations on Plate A-20. The piezometers are currently being observed at 3-month intervals.

8.3 Embankment Crest Movement Markers. Eleven crest movement markers (six in the east embankment and five in the west embankment) were installed along the downstream edge of both embankment crests late in 1965. The markers consist of small round concrete posts which are embedded in the embankment to a depth of about 4 feet and contains a 1/2 inch diameter rebar extending from the center of the post from which vertical and horizontal surveys are taken. Plan locations and recorded observations of the markers are shown on Plate A-21. The markers are currently on a 5-year observation interval.

Vertical and horizontal surveys taken on these monuments since the initial observations in January 1966 indicate that the movements are all within reasonable limits for these embankments.

Vertical movement plots indicate that the embankments have progressively settled at a generally decreasing rate since construction, and that the maximum settlement at each embankment occurs at the maximum section of

embankment, which, coincidentally, happens to be the closure section of the embankments. The maximum settlements are about 0.57 feet for the west embankment and 0.85 feet for the east embankment.

Plots of vertical movement versus time indicate that the rate of embankment consolidation and foundation settlement has substantially subsided in the past several years, and as such it would be anticipated that the total settlement would not increase significantly in future years. Considering the amount of overbuild (1 foot for the west embankment and 2 feet for the east embankment), the total settlement to date, and the declining settlement rate it is concluded that the total settlement will not exceed the overbuild.

Horizontal movement plots for the embankments indicate the normal pattern of movement usually associated with a reservoir loaded embankment, i.e., a general movement in the downstream direction with the maximum movement occurring near the maximum section of embankment. The maximum amount of downstream movement is about 0.35 feet for the west embankment and about 0.41 feet for the east embankment.

8.4 Intake Structure Movement Inserts. Four movement insert markers are located in the top of the concrete intake structure as shown on Plate A-22. Periodic observations of these markers, since initial survey in January 1967, are plotted on Plate A-22. These generally indicate a slight tilt toward the downstream and left abutment direction. Time plots indicate a slow uniform settlement of all points up through January 1974 followed by a sharp rebound in December 1974 and May 1977 and then a sharp settlement again in November 1979. Surveys of other Salt Creek project intake structures reveal similar patterns of movement, all of which may be associated with changes in temperature. The overall total and differential movements of the structure, however, are small and within generally accepted tolerance levels for such a structure.

8.5 Conduit Invert Profile Survey. Profile surveys of the CMP conduit have been conducted at points along the invert of the conduit to check

settlement characteristics. The initial survey was performed on 10 July 1969. A later profile was taken on 5 July 1974. The profiles indicate that the conduit beneath the maximum embankment section has settled as expected. A maximum camber of 1.0 foot was built into the conduit at the axis of the dam to allow for eventual settlement. The last profile indicates that the conduit had settled about 1.0 foot. The profiles also indicate a nearly straight line profile from upstream to downstream invert. A drawing of the invert profile survey results is shown in Periodic Inspection Report No. 1, April 1974. Relining of the conduit has eliminated the original data base. New surveys are being obtained.

9. CONSTRUCTION HISTORY.

9.1 General. Detailed construction records were destroyed in June 1975. Information presented herein was obtained from the remaining permanent files concerning the contracts and some correspondence files.

The Contractor for the project was Brandt Construction Incorporated, Lincoln, Nebraska. The contract was awarded on 15 December 1964. Work was then ordered to proceed on 29 December 1964 and the project construction was completed on 30 November 1965. The contract work was performed without modifications.

10. OPERATIONAL HISTORY AND PERFORMANCE.

10.1 Operation and Maintenance Procedures. The Secretary of the Army granted to the State of Nebraska Game and Parks Commission, a license to use and occupy the land and water areas of the project for public recreation purposes. For consideration of the privileges granted, the State was required to maintain the project in a manner acceptable to the District Engineer. In general this requires only routine maintenance. Any major repairs to either the embankment, outlet works or spillway are accomplished by the Corps of Engineers. The Corps of Engineers opens the intake structure gates annually to assess operating capability and periodically monitors project instrumentation.

10.2 Inspections. In depth periodic inspections are conducted at 5-year intervals in accordance with ER1110-2-100, "Periodic Inspections and Continuing Evaluation of Completed Civil Works Projects." These periodic inspections are made jointly by representatives of the Operations and Engineering Divisions of the Omaha District Corps of Engineers and by representatives of the Missouri River Division Office. Periodic inspections were made in April 1974 and in October 1979, and are reported in Periodic Inspection Reports No. 1 and No. 2, respectively. These reports include the results of the inspection and an evaluation of the embankment and structural performance based on the inspection and instrumentation observations.

Additional informal inspections are performed by the Operations Division annually, and by Area personnel on a monthly basis.

A surveillance plan is presently being prepared to establish a frequency for inspections and instrument observations based on the need at each particular Salt Creek Dam.

10.3 Reservoir Levels. Reservoir elevations are determined daily on a strip chart water stage recorder. Additional verifications of these readings are determined periodically from the staff gage mounted on the intake structure. Fluctuations of the reservoir since mid-1967 are plotted on Plate A-20. The highest reservoir level on record occurred at 1:15 p.m. on 11 October 1973 when it reached elevation 1344.51, about 3.5 feet above normal operating pool elevation 1341.0 and about 10.5 feet below the spillway crest elevation of 1355.0.

10.4 Significant Operational Events.

10.4.1 Riprap. During an inspection in 1969 and all annual inspections up to and including the first periodic inspection in 1974; it was noticed that the limestone riprap slope protection was gradually deteriorating, and that several areas had settled enough so that the top of the stone was below the design top elevation. The periodic inspection report recommended that the riprap be repaired and that an access road be constructed on

the face of the dam above the riprap for routine repair or replacement of the riprap. Subsequently, in 1975, the Area Office of the Omaha District placed additional limestone riprap on the existing stone and constructed a small access road at the top of the riprap. Crushed limestone rock was also placed on the crests of both embankments. The riprap and crushed rock were obtained from Hopper Brothers quarry near Ashland, Nebraska. Photos 2 through 7 show various views of the riprap, access road berm and gravel crests.

10.4.2 Repair of Outlet Conduit and Plunge Pool. During the first periodic inspection of the project in April 1974, it was found that small amounts of seepage were entering the conduit from 50 percent of the field and 5 percent of the shop joints. The seepage areas were generally on both sides of the conduit and occurred mainly below the spring line of the conduit. Additionally, sounding tests indicated a possibility of voids adjacent to the conduit.

Subsequently, in September 1977, a contract was awarded to Technical Inspection Corp of Lincoln, Nebraska (Contract No. 77-C-0101) to grout the voids in the backfill around the conduit, and to reshape the cut slopes of the plunge pool which had been damaged due to erosion.

The majority of the grouting operation was confined to the center 100 feet of the conduit; from station 0+46 to 1+46. For this portion of the pipe, small holes of approximately 1 inch diameter were drilled through the conduit wall spaced at 5-foot intervals, and then grout was pumped into each hole. A total of 42 holes were drilled for this portion of the pipe. For the remainder of the pipe, void locations were determined by sounding with a hammer. Once voids were determined, then holes were drilled and grouting accomplished. A total of 50 holes were drilled but only 6 took grout. Two were within the center 100-foot section and four were located downstream from that section. Grouting was completed in January 1978.

The grout mixture consisted of one sack of cement, 100 to 150 pounds of fine granular bentonite, and 60 gallons of water. The total grout take included three bags of cement and 400 pounds of bentonite.

Additional rehabilitative measures were accomplished on the outlet conduit in 1980. Because of a general deterioration of the bituminous lining and corrosion holes which completely penetrated the corrugated metal conduit at this project and also at Sites 2, 9 and 10, it was decided to install a 30-inch diameter 3-1/2-inch thick precast reinforced concrete pipe lining inside of the 42-inch diameter corrugated metal pipes. A contract for this work was awarded on 9 May 1980 to Dobson Brothers Construction Company of Lincoln, Nebraska, under contract number 80-B-0151. The final contract amount for the four sites was \$238,699. The work consisted essentially of furnishing and installing the concrete pipe liners, grouting the annular space between the pipes, and installing air vents for the pipes. The precast pipe lining was specified to conform to ASTM C76, Class V wall, B pipe. Steel ring joints with round rubber gaskets were required.

Grouting of the annular space between the liner and the CMP was accomplished by pumping the grout through grout injection holes which had been cast in the pipe sections. Grouting operations proceeded from the downstream end of the pipes to the upstream end. Injection was usually done in the invert injection hole and continued until grout appeared at the vent hole in the crown.

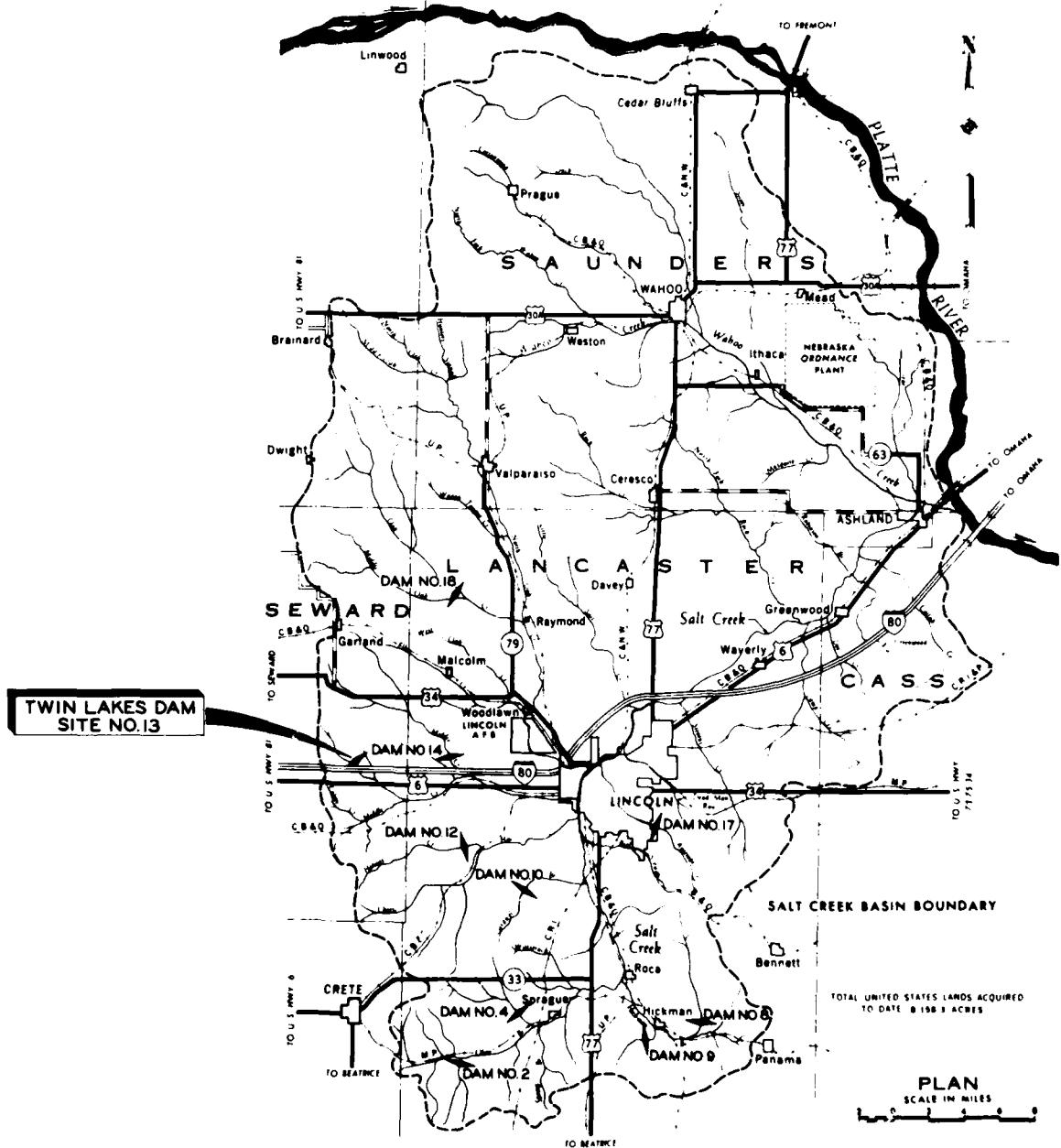
The grout consisted of portland cement, fly ash, fine aggregate, fluidifier and water. The cementitious material consisted of 70 percent portland cement and 30 percent fly ash by absolute volume. The fine aggregate in the grout mix was not to exceed a ratio of three parts aggregate to one part cementitious materials. The water cement ratio was not to exceed 0.55 by weight. The fluidifier was added to the grout mix in a sufficient quantity to produce an expansion of 3 to 5 percent. Photo No. 12 shows a typical grout pumping operation and Photo No. 13 shows a view of the conduit after grouting is completed.

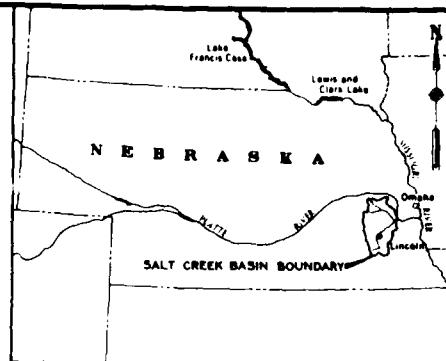
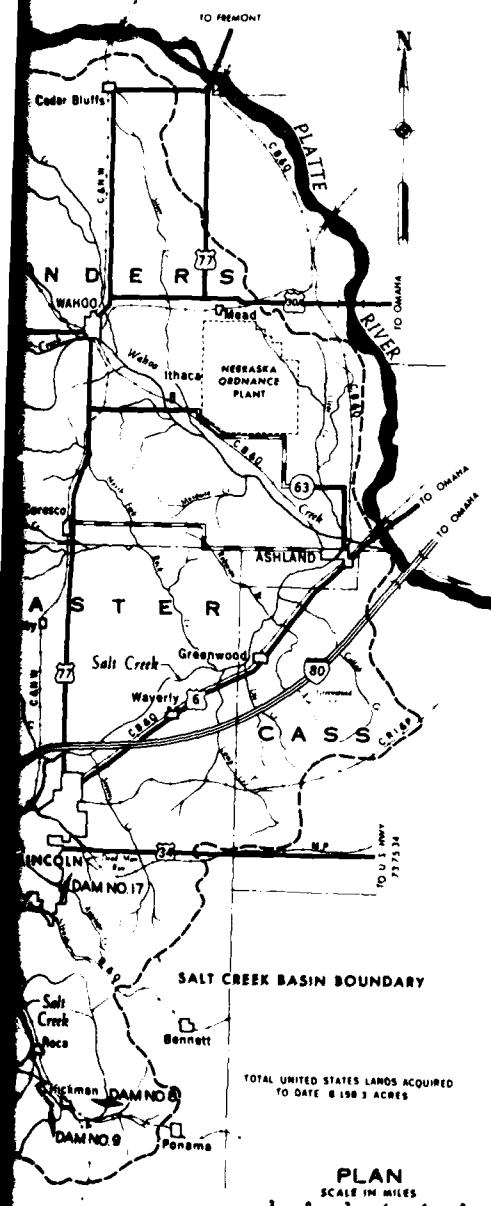
10.4.3 Seepage. Three very small seepage areas were found during the first periodic inspection in April 1974. Two of the seepage areas were found in the old creek channels near the downstream toe of each of the dams, the third was found in the left slope of the plunge pool at the outlet of the

discharge conduit. As a result of these findings, the five well point type piezometers, previously discussed, were installed in 1976 at select locations to monitor piezometric levels in these areas. The seepage areas, in all subsequent inspections, including the periodic inspection in 1979, appeared much drier than initially found. Piezometric data from the piezometers indicate no unusual conditions.

10.5 Performance. The Twin Lakes Dam and appurtenant structures are in good condition. Since 1965, when the project was completed, periodic, annual and monthly inspections and evaluations of the instrumentation data have revealed no significant problems concerning the safety of the dam. Since the reservoir was formed in 1967, the maximum reservoir level attained was about 3.5 feet above normal operating pool level and about 10.5 feet below the spillway crest. The project is well maintained, and because of its relative close proximity to the Omaha District Offices, it can readily be inspected if potential problems develop. Maintenance problems which have developed, such as the deterioration of the conduit lining, generally are rectified before they turn into major problems which may subsequently affect the integrity of the dam.

APPENDIX A
DRAWINGS



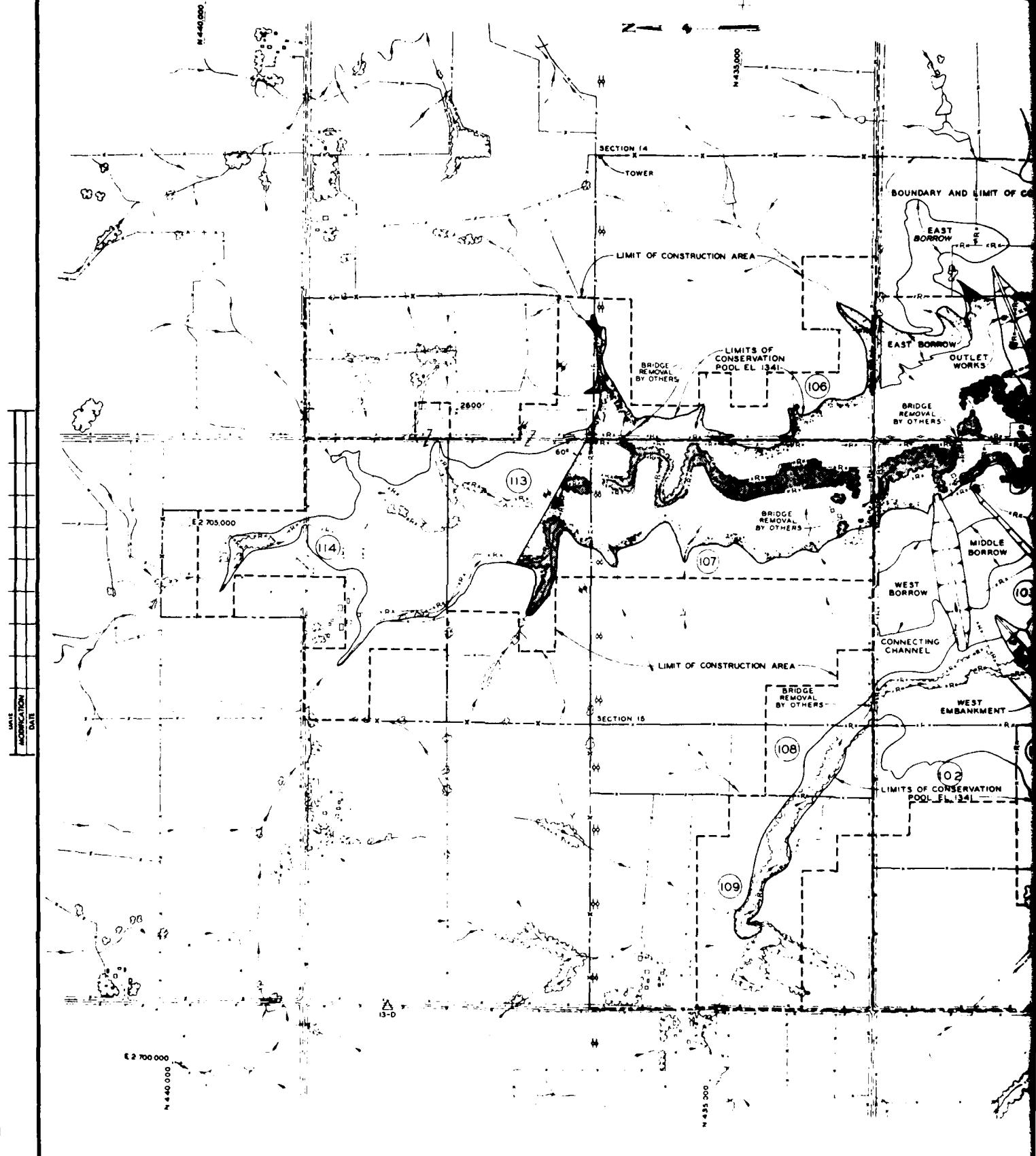


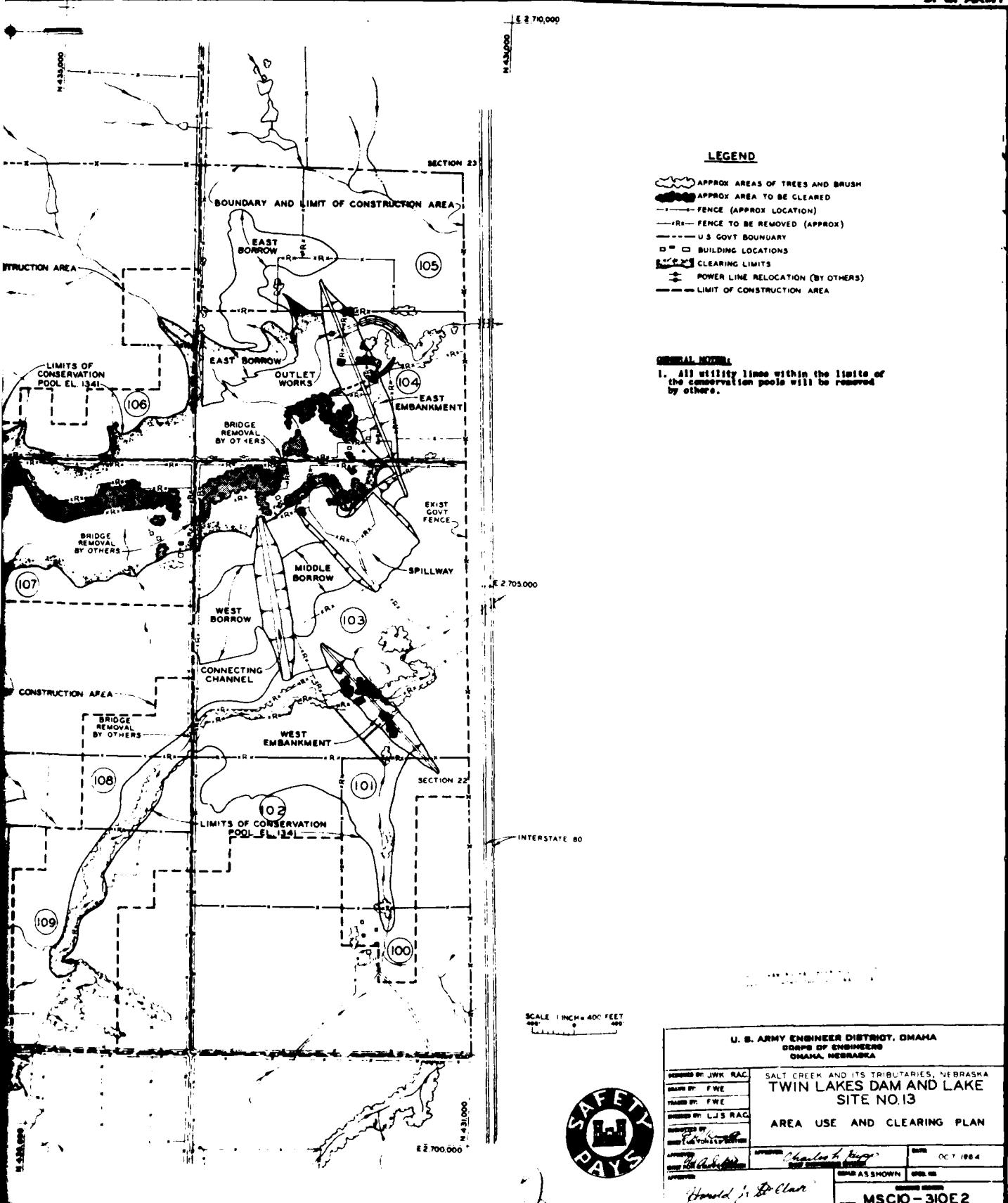
LOCATION MAP

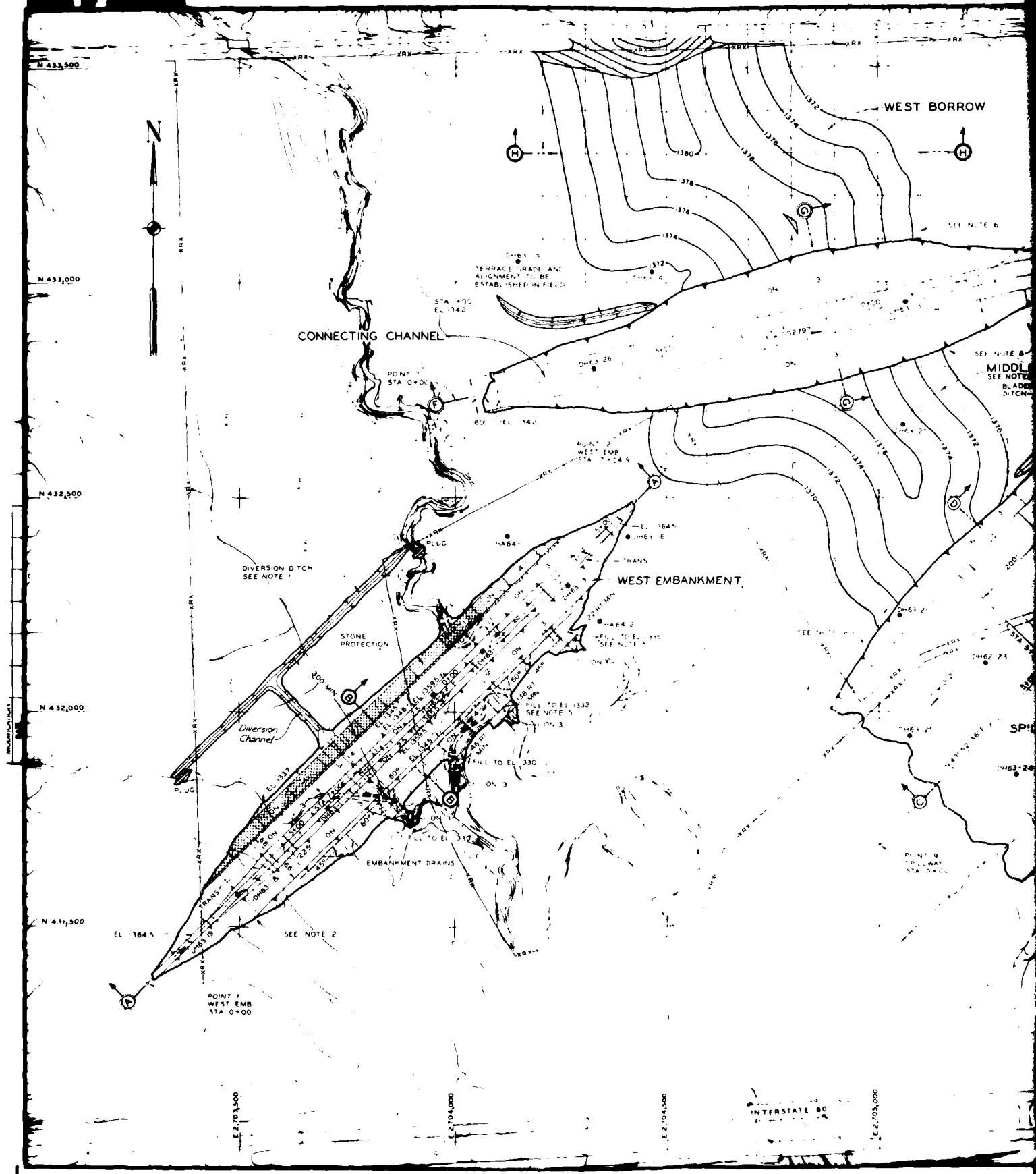
DATE	DESCRIPTION	MADE	APPROV'D
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
SITE NO.	SALT CREEK AND ITS TRIBUTARIES, NEBRASKA TWIN LAKES DAM AND LAKE SITE NO.13		
DESIGN BY:	PROJECT LOCATION MAP		
SP. BY:			
REV'D BY:			
APPROV'D BY:			
DATE:	REVISIONS	MADE	APPROV'D
THIS DRAWING HAS BEEN REDUCED TO ONE-FIFTH OF THE ORIGINAL SCALE			
THIS PLAN ACCOMPANIES CONTRACT NO. DACA43 MODIFICATION NO.			
E. & L. ENGINERS INC.			
EMBANKMENT CRITERIA AND PERFORMANCE REPORT			
1982 PLATE A1			

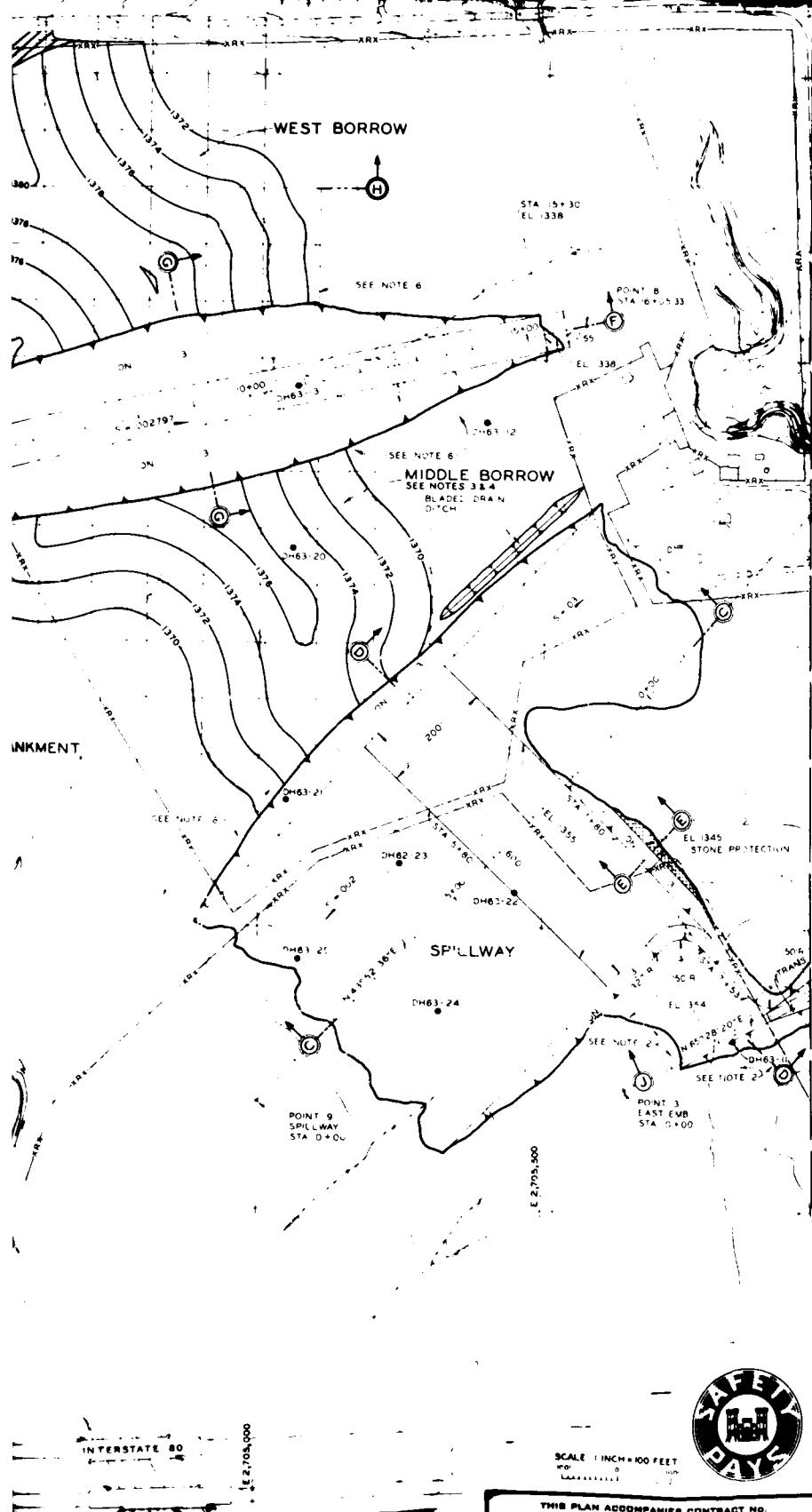


CORPS OF ENGINEERS









LOCATION OF POINTS

COORDINATES

POINT	STATION	NORTH	EAST	BEARING
1	Hub. West 0+00	431370	2703285	
2	Hub. West 17+04.19	432355	2704500	N45°28'38"E
3	Hub. East 0+00	431720	2705550	
4	Hub. East 22+64.33	432660	2707710	N65°28'20"E
5	Hub. East 16+95 = O.W. Sta. 0+00	432423.65	2707192.04	
6	Outlet Wks. P.I.	432041.55	2707366.40	S94°31'40"E
7	Cn. Ch. 0+00	432725	2704000	
8	Cn. (Ch. 16+05.33	433060	2705570	N77°57'18"E
9	S.W. 0+00	431690	2705000	
10	S.W. 14+42.77	432730	2706000	N43°52'36"E
11	S.W. Sta. 5+00	432050.42	2705346.55	

Curve "A" Outlet Wsp., 420' from Axis

△ 70°30' R
D 30°00' R
T 134.98'
L 235.00'
R 190.99'

GENERAL NOTES:

1. The exact alignment, grade, width and side slopes of the diversion ditches and plugs will be selected by the Contractor, subject to approval. The ditches are optional if other means are used to provide drainage in upstream of the embankment areas.
 2. Natural terraces shall be maintained against the embankment so as to prevent drainage along the embankment toe.
 3. Adjacent to the borrow areas and at locations selected by the Contractor, subject to approval, the Contractor shall stockpile the following amounts of topsoil:

West borrow	- - - - -	7,000 Cu. Yds.
Middle borrow	- - - - -	5,000 Cu. Yds.
East borrow	- - - - -	11,000 Cu. Yds.
 4. No stockpile shall be placed below RL 1341.
 5. Borrow area grading shall be accomplished to the approximate new contours shown.
 6. Waste material shall be placed in the channel fills at the downstream toe of the embankments. The waste material shall be placed in 2' lifts and traffic compacted as directed.
 7. All elevations shown refer to feet above M.S.L., 1954 General Adjustment.
 8. For sections and profiles, see dwg. 310E5 & 310E7
 9. For legend, see dwg. 310E4

CO-ORDINATES ON SECTION CORNERS

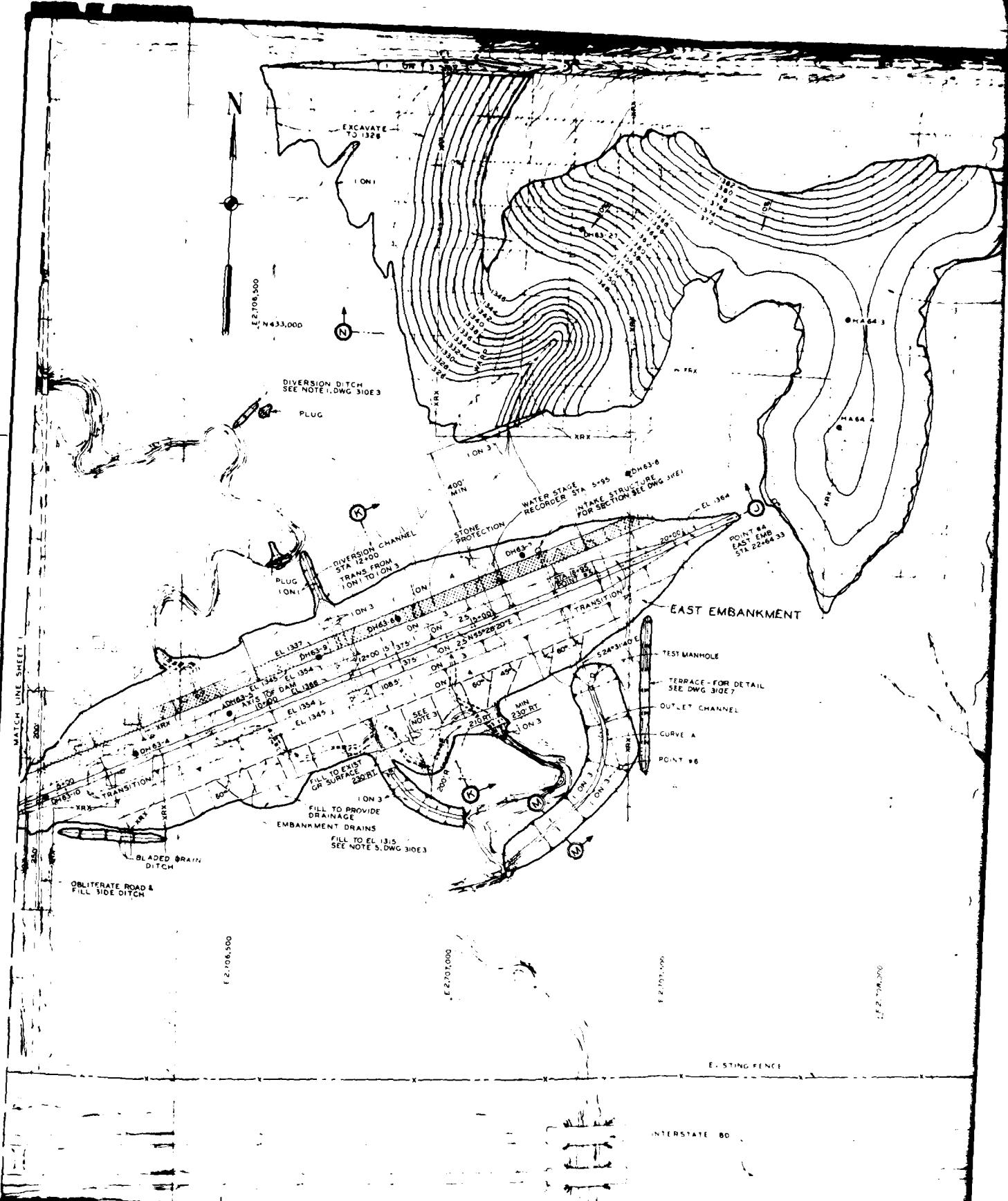
CORNER	N.	S.
NW COR.	22	433,475.54
NE COR.	22	433,350.34
SW COR.	22	433,526.22
SE COR.	23	433,670.74
CENTER	23	431,030.13
E. S. COR.	22	430,986.57
CENTER	22	430,911.53
W. S. COR.	22	431,593.97

THIS DRAWING HAS BEEN REDUCED TO
THREE-FIFTHS THE 1/8 INCH SCALE

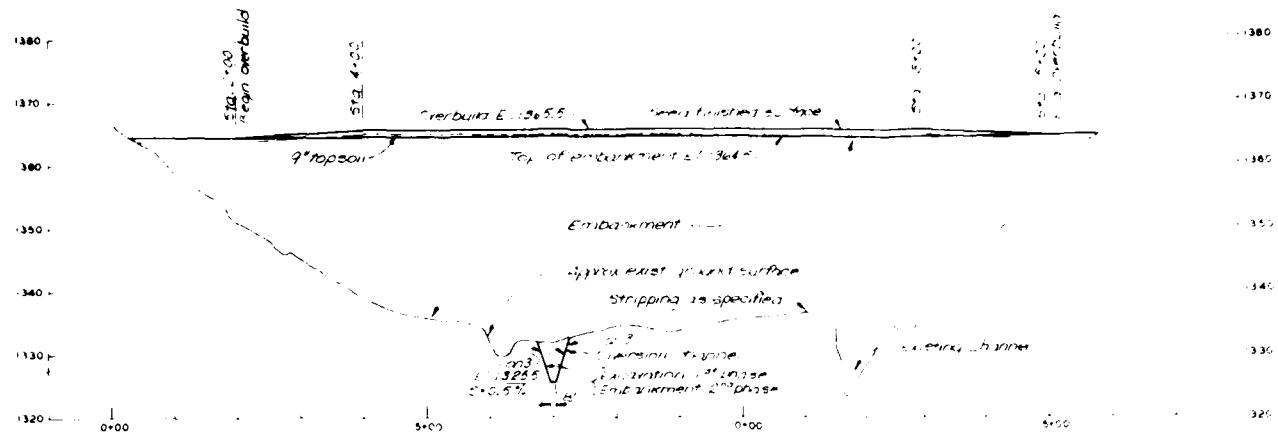
2-2-66		REVISED TO SHOW AS BUILT CONDITIONS			
DATE		DESCRIPTION		MADE APPROD	
		REVISIONS			
<p style="text-align: center;">U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA</p>					
DESIGNED BY		SALT CREEK AND ITS TRIBUTARIES, NEBRASKA			
DRAWN BY <i>L. D. C.</i>		DAM AND RESERVOIR SITE 13			
CHECKED BY <i>D. C.</i>		EXCAVATION AND EMBANKMENT PLAN			
APPROVED BY <i>J. H. K.</i> DIRECTOR OF ENGINEERING		SHEET 1			
APPROVED BY <i>John Blair</i> DIRECTOR OF MAPS & SURVEYS		APPROVED <i>Charles L. Blair</i>		DATE <i>10-10-66</i>	
APPROVED		GRADE AS DRAWN		SPEC. NO. 10-310E-63-85	
<i>John Blair</i>		DRAWING NUMBER MSC 10-310E 3.1		RD	
U. S. ARMY ENGINEER DISTRICT, OMAHA					

AMENDMENT
DATE
MODIFICATION
DATE

MATCH LINE SHEET

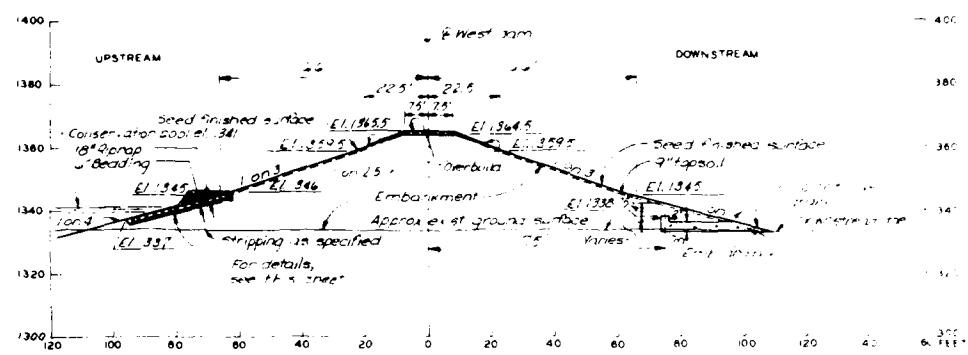


CORPS OF ENGINEERS



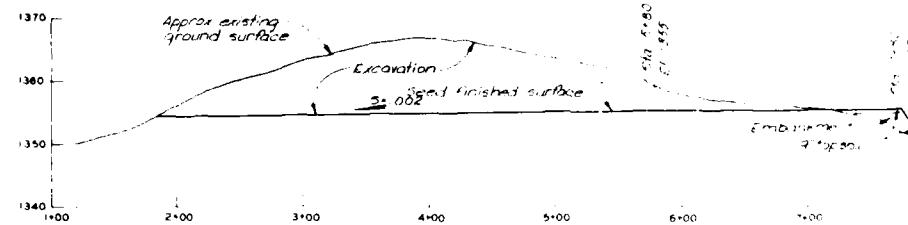
SECTION A-A

WEST EMBANKMENT PROFILE
SCALE HORIZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



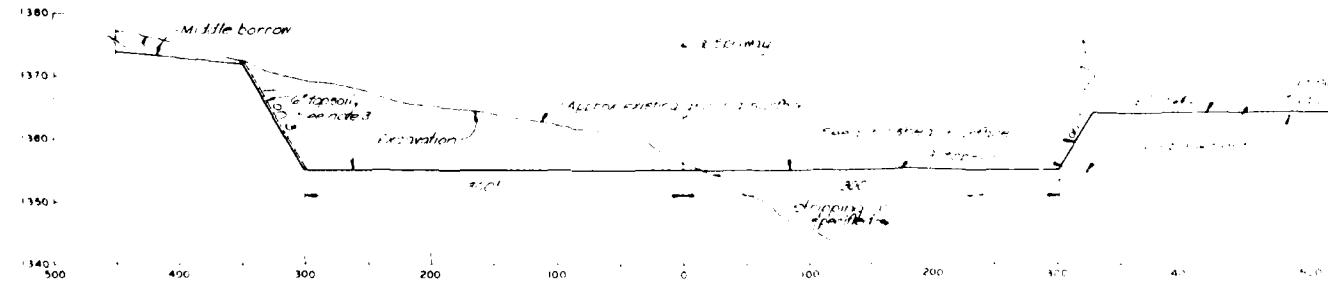
WEST EMBANKMENT SECTION B-B

SCALE 1 INCH = 20 FEET
20 0 20



SECTION C-C

SPILLWAY & PROFILE
HORIZ 1 INCH = 50 FEET
VERT 1 INCH = 10 FEET



SPILLWAY SECTION D-D

SCALE HORIZ 1 INCH = 50 FEET
VERT 1 INCH = 10 FEET

15'00
5'00
Crown
Elevation

+380

+370

+360

420' of 10' deep

+340

+360

+350

+330

+350

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+310

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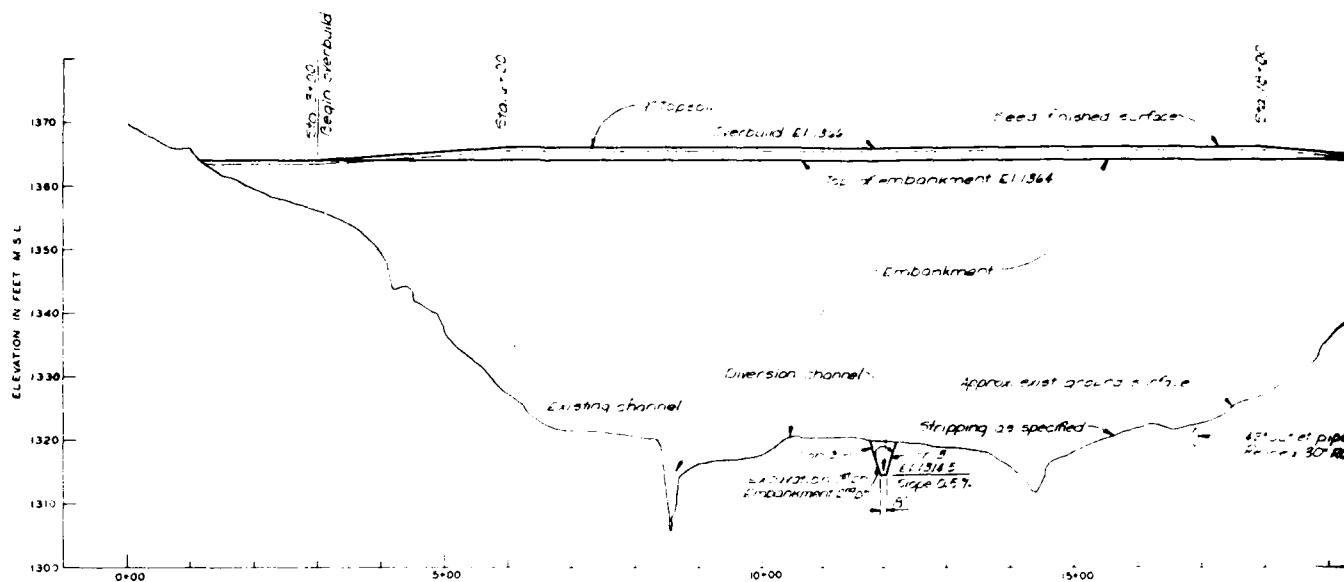
-760

-780

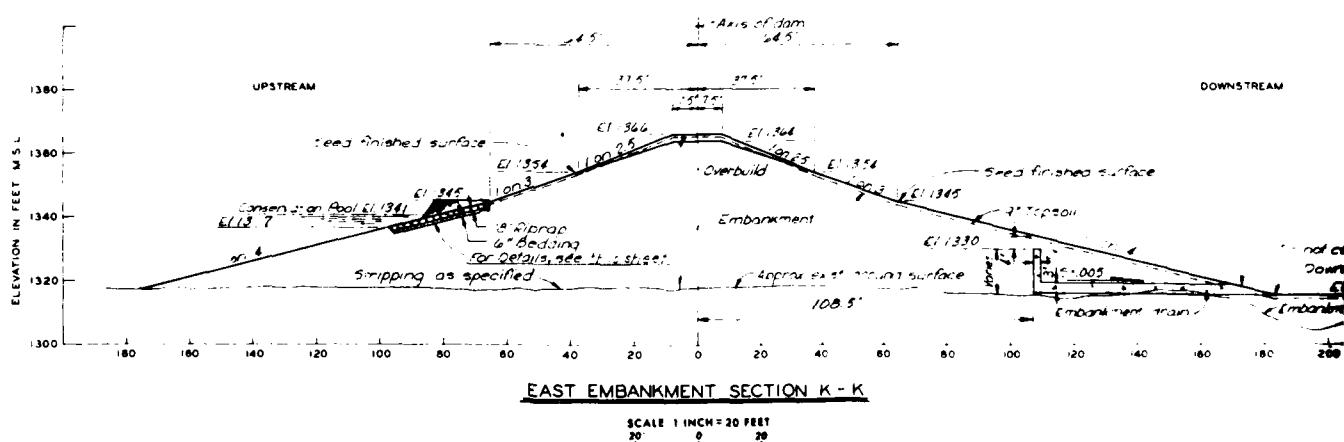
-760

-770

CORPS OF ENGINEERS

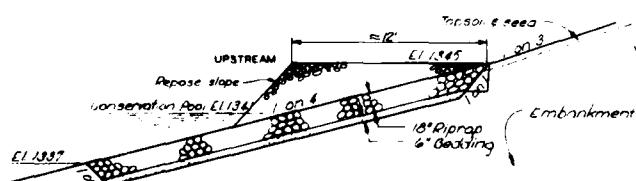


SECTION J - J
EAST EMBANKMENT PROFILE
SCALE HORIZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



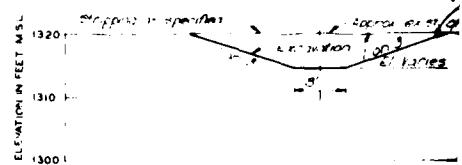
EAST EMBANKMENT SECTION K - K

SCALE 1 INCH = 20 FEET



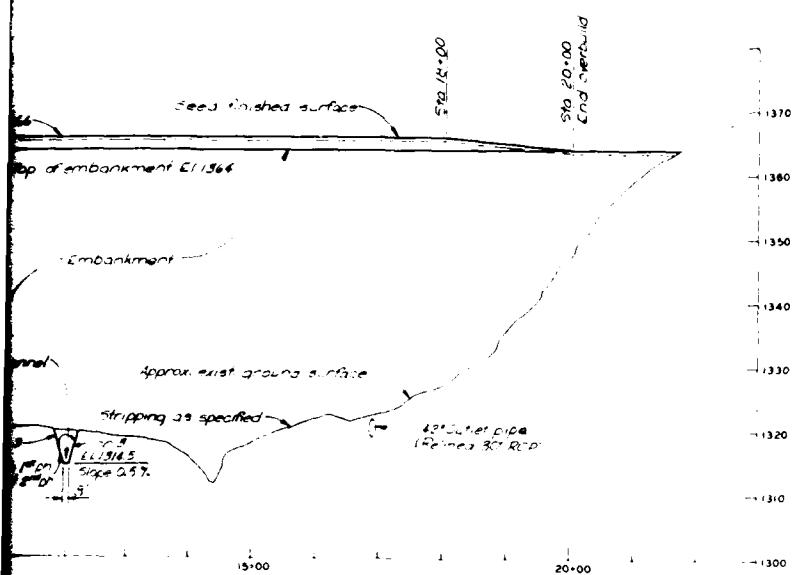
EAST EMBANKMENT RIPRAP DETAIL

SCALE 1 INCH = 5 FEET



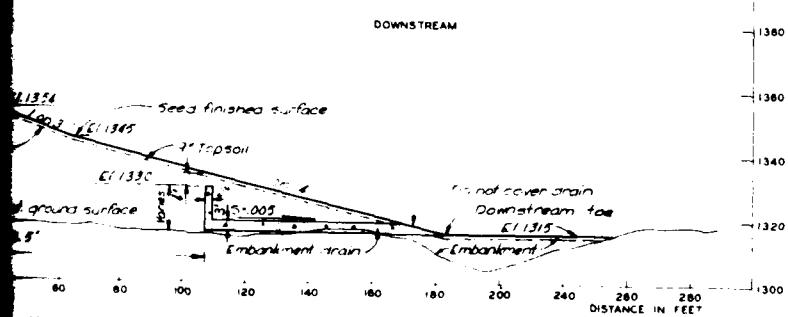
TYPICAL DIVERSION CHANNEL THRU EAST EMBANKMENT

SCALE 1 INCH = 10 FEET



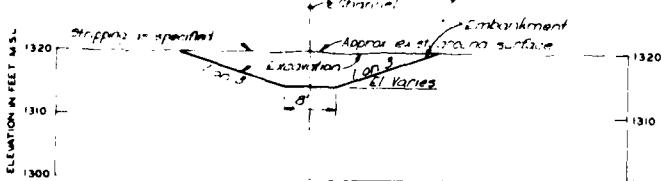
SECTION J-J

EMBANKMENT PROFILE
HORZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



GENERAL NOTES

1. All elevations shown refer to feet above N.A.S., 1934 Com adj.
2. For location of Sections and Profile, see fig. 310E4



TYPICAL DIVERSION CHANNEL SECTION
THRU EAST EMBANKMENT

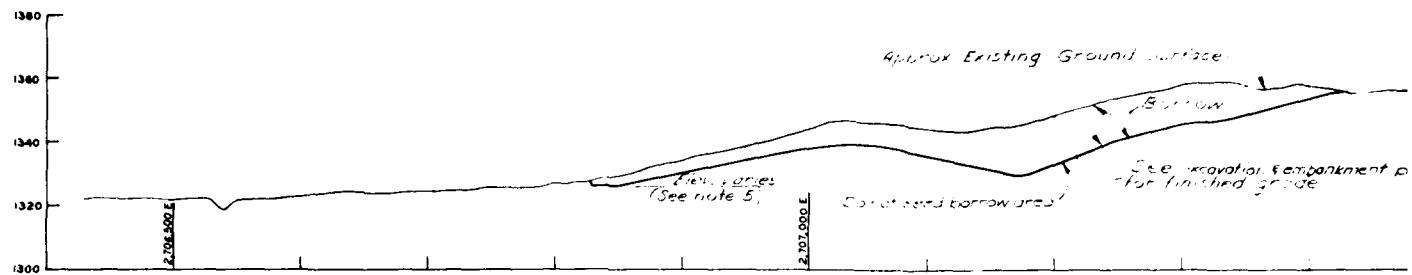
SCALE 1 INCH = 10 FEET

THIS PLAN ACCOMPANIES CONTRACT NO.
DA-28-066-45-90 MODIFICATION NO.



REvised to show "AS BUILT" CONDITIONS	<i>J.E. Hogg</i>
DATE	10/1964
DESCRIPTION	MADE APPROVED
J. E. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA	
DRAWN BY: J.W.K.	SALT CREEK AND ITS TRIBUTARIES, NEBRASKA
DESIGN BY: R.A.P.	DAM AND RESERVOIR, SITE 13
TECHN BY: R.A.P.	EAST EMBANKMENT
CHECKED BY: L.J.B.	PROFILE, SECTIONS AND DETAILS
APPROVED BY: <i>J.E. Hogg</i>	DATE: OCT 1964
APPROVED BY: <i>Charles T. Hogg</i>	REVISIONS: 1000-40-30-00-00-28
APPROVED BY: <i>Shirley S. Clark</i>	THIS PLAN ACCOMPANIES CONTRACT NO. DA-28-066-45-90 MODIFICATION NO.
APPROVED BY: <i>MSC10-310E6.1</i>	DATE: 10/1964

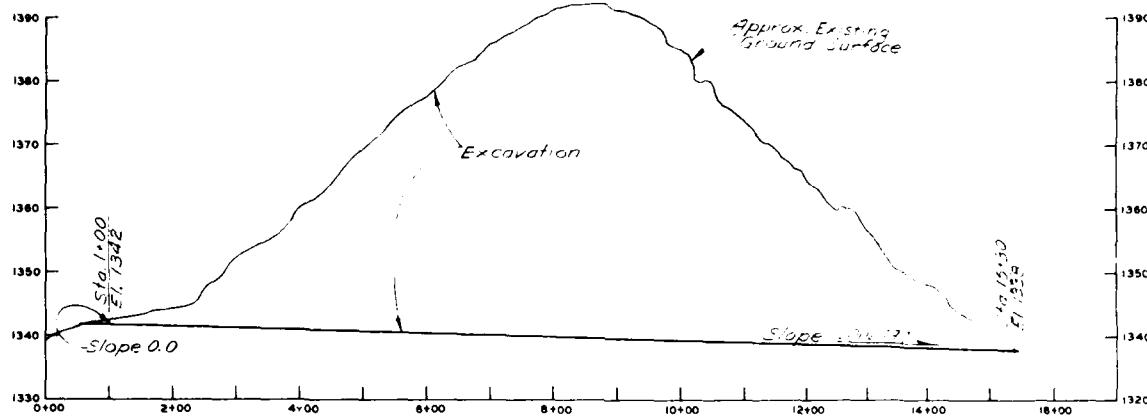
CORPS OF ENGINEERS



EAST BORROW SECTION N-N

SCALE HORIZ 1 INCH = 50 FEET

SCALE VERT 1 INCH = 20 FEET

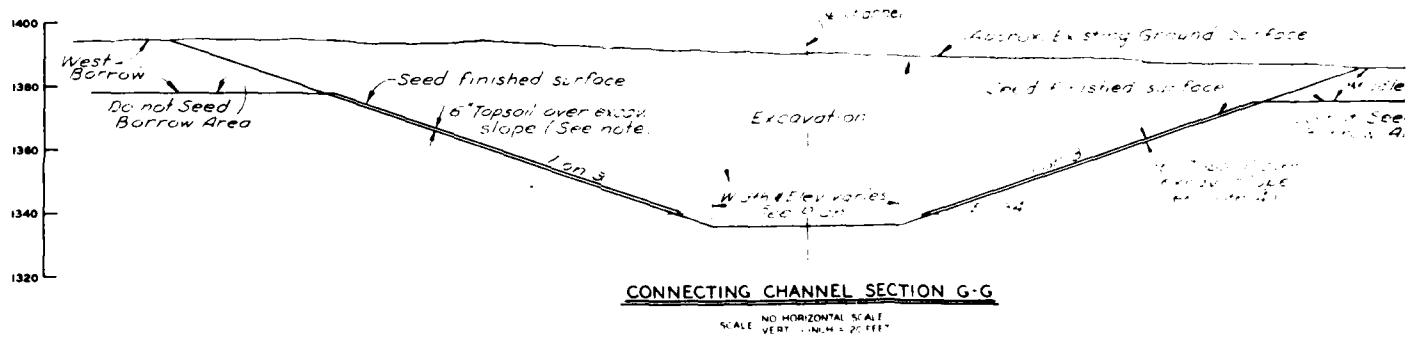


SECTION F-F

CONNECTING CHANNEL PROFILE

SCALE HORIZ 1 INCH = 100 FEET

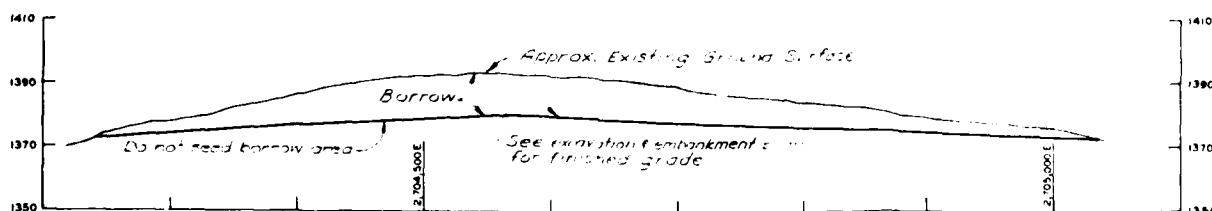
SCALE VERT 1 INCH = 20 FEET



CONNECTING CHANNEL SECTION G-G

SCALE NO HORIZONTAL SCALE

SCALE VERT 1 INCH = 20 FEET

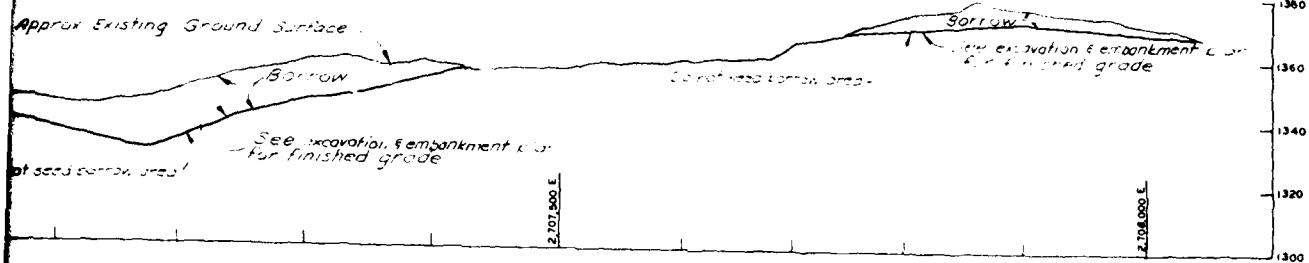


WEST BORROW SECTION H-H

SCALE HORIZ 1 INCH = 50 FEET

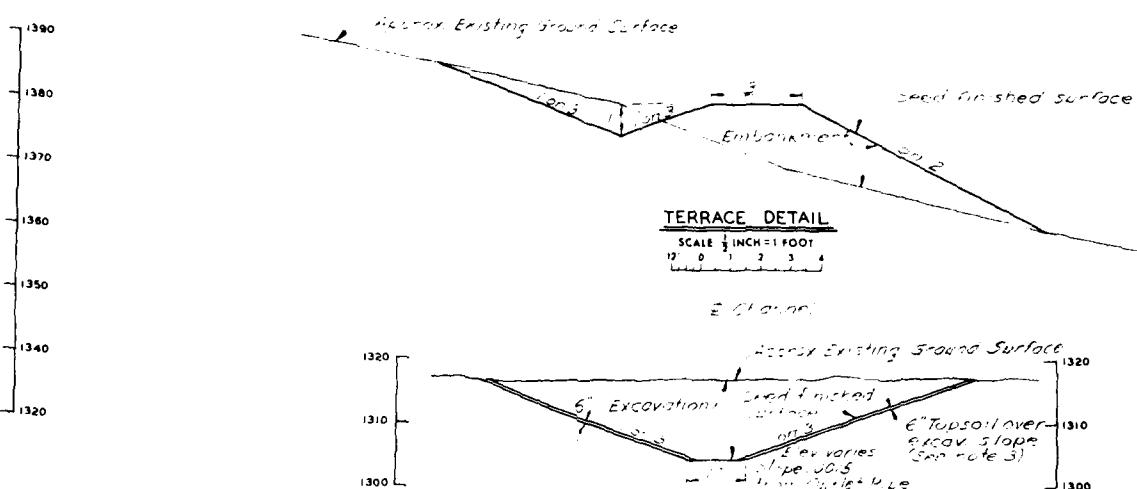
SCALE VERT 1 INCH = 20 FEET

U. S. ARMY



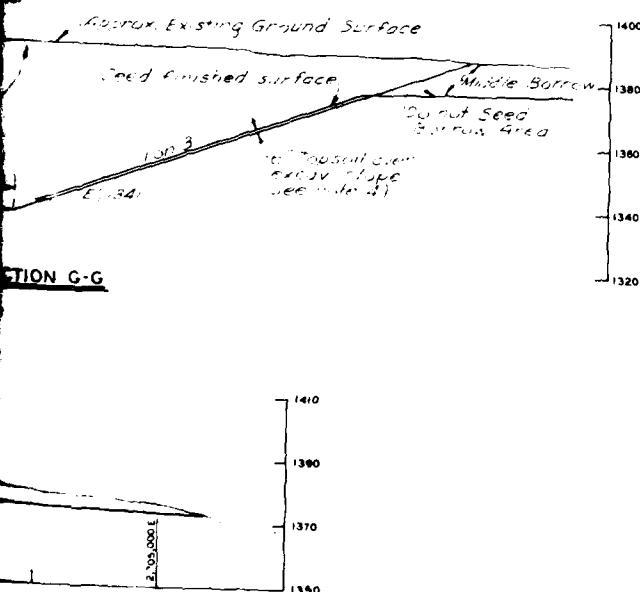
EAST BORROW SECTION N-N

SCALE HORIZ 1 INCH = 50 FEET
VERT 1 INCH = 20 FEET



OUTLET WORKS CHANNEL SECTION M-M

SCALE 1 INCH = 10 FEET



GENERAL NOTES

1. All elevations refer to feet above M.S.L., 1954 General Adjustment.
 2. For location of sections and profiles see Diagram 310-3024.
 3. **Bl. 310-3024**:
a. Bl. 310-3024 layer of topsoil over excavated 1 on 3 slopes of outlet works channel, from bottom of channel to top of slope.
 4. Place Bl. 310-3024 layer of topsoil over excavated 1 on 3 slopes of connecting channel, from Bl. 310-3024 to top of slope after removal of horizon. We did not place topsoil in channel bottom.
 5. The lower most horizon elevation of the East Borrow Area is shown at Bl. 310-3024, however in order to balance the earthwork excavation horizon and enhancement this elevation will be raised or lowered as may be

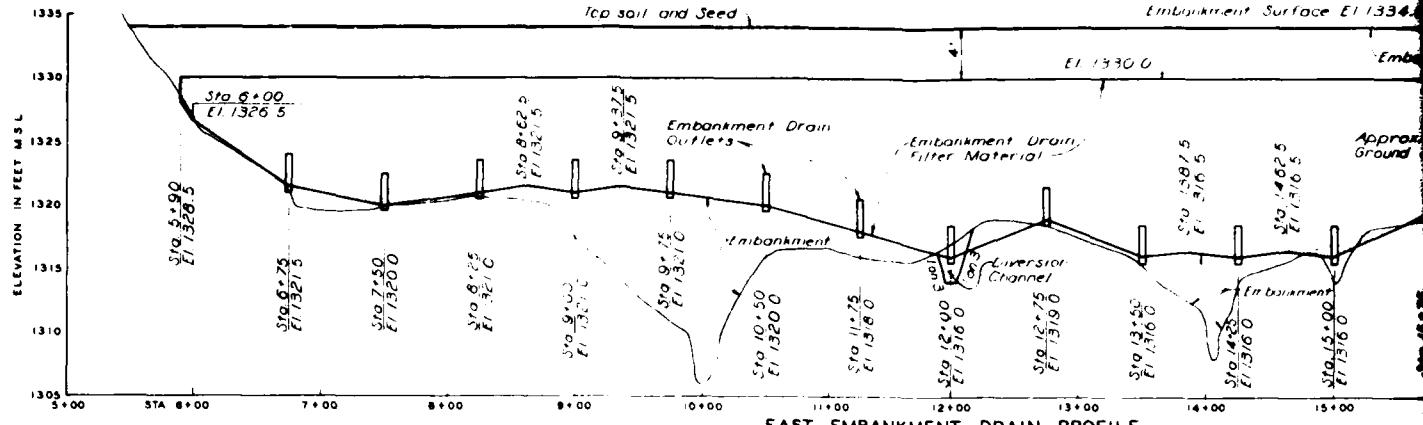
THIS DRAWING HAS BEEN REDUCED TO
1/5 FULL SIZE FOR THE CONVENIENCE OF THE
CARRIER.

2-2-66		REVISED TO SHOW "AS BUILT" CONDITIONS	W.E.F.
DATE		SUPERINTENDENT	MADE
		REVISIONS	APPROVED
<p style="text-align: center;">U. S. ARMY ENGINEER DISTRICT, OMAHA</p> <p style="text-align: center;">DIVISION OF ENGINEERS</p> <p style="text-align: center;">OMAHA, NEBRASKA</p>			
<p style="text-align: center;">SALT CREEK AND ITS TRIBUTARIES, NEBRASKA</p> <p style="text-align: center;">DAM AND RESERVOIR, SITE 13</p> <p style="text-align: center;">CONNECTING CHANNEL & BORROW AREAS</p> <p style="text-align: center;">SECTIONS AND DETAILS</p>			
<p>REMOVED BY: J. W. R.</p> <p>REMOVED BY: A. P. C.</p> <p>REMOVED BY: A. P. C.</p> <p>REMOVED BY: L. J. S.</p> <p>REMOVED BY: <i>[Signature]</i> T. E. O. S. D. E. N. R.</p> <p>REMOVED BY: <i>[Signature]</i> T. E. O. S. D. E. N. R.</p>		<p><i>Charles F. Higgin</i></p>	<p>DATE: OCT 1966</p> <p>SCALE AS SHOWN</p> <p>0000 00 00 00 00 00 00</p>
<p><i>Donald L. Blair</i></p>			



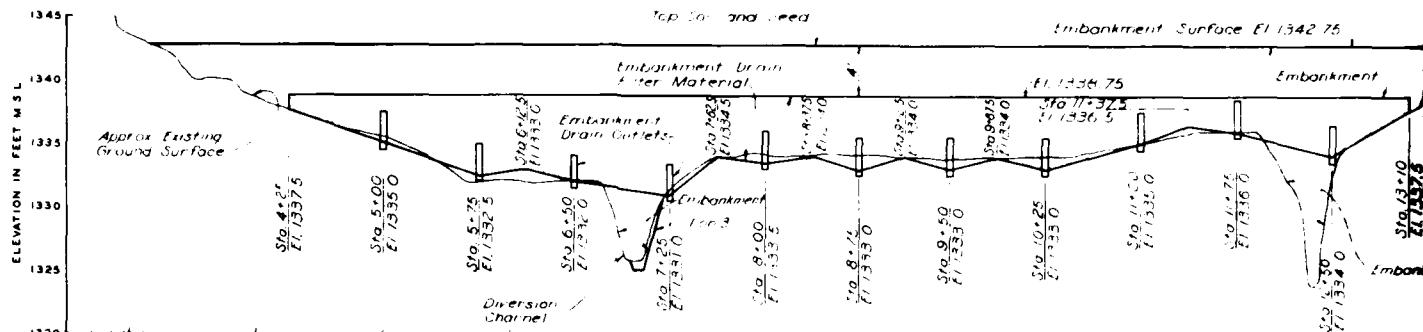
THIS PLAN ACCOMPANIES CONTRACT NO.
DA-38-388-~~xx~~-82-84

CORPS OF ENGINEERS



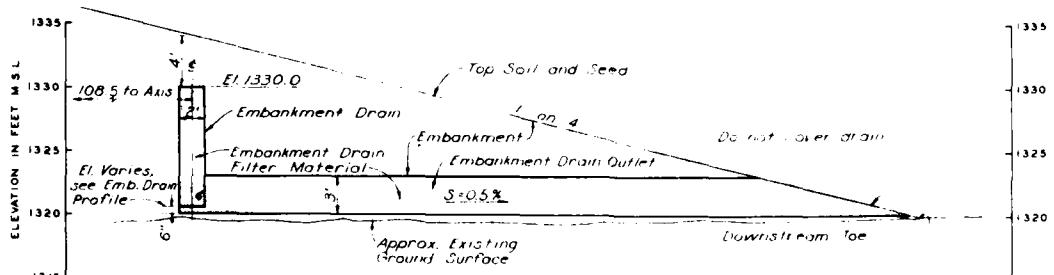
EAST EMBANKMENT DRAIN PROFILE

SCALE VERT 1 INCH = 5 FEET
HORIZ 1 INCH = 50 FEET



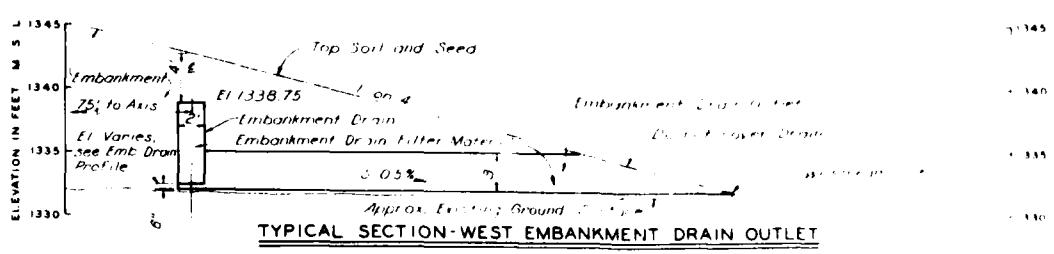
WEST EMBANKMENT DRAIN PROFILE

SCALE VERT 1 INCH : 5 FEET
HORIZ 1 INCH : 50 FEET



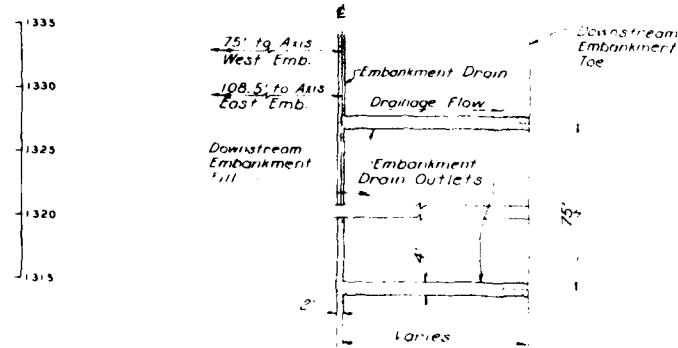
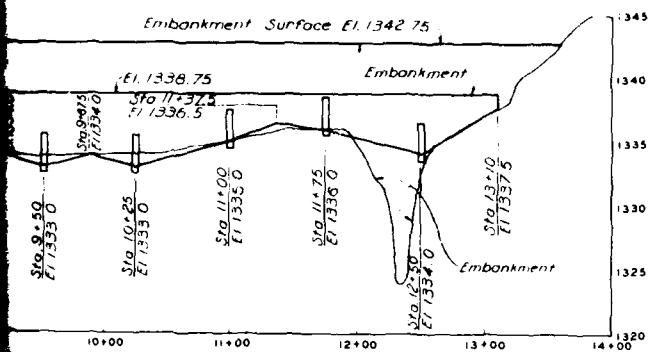
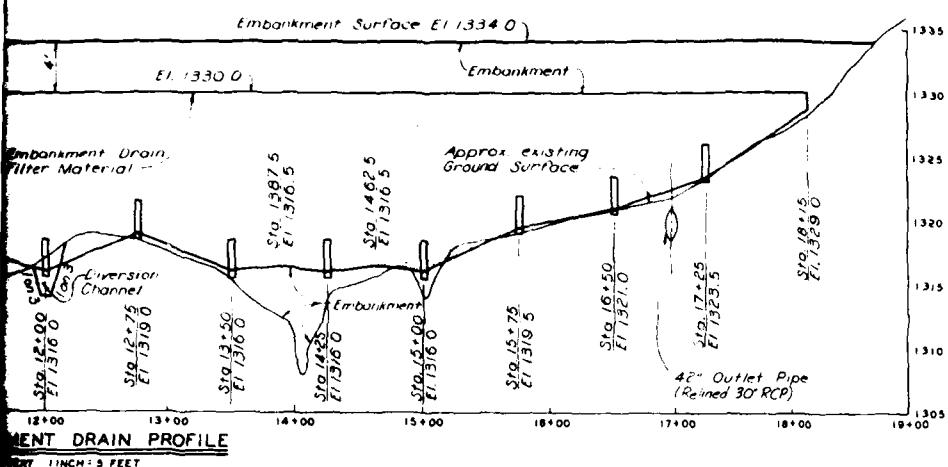
TYPICAL SECTION - EAST EMBANKMENT DRAIN OUTLET

SCALE 1 INCH : 3 FEET



TYPICAL SECTION-WEST EMBANKMENT DRAIN OUTLET

SCALE 1 INCH = 5 FEET



PLAN-TYPICAL PERVIOUS DRAIN OUTLET

SCALE 1 INCH : 20 FEET

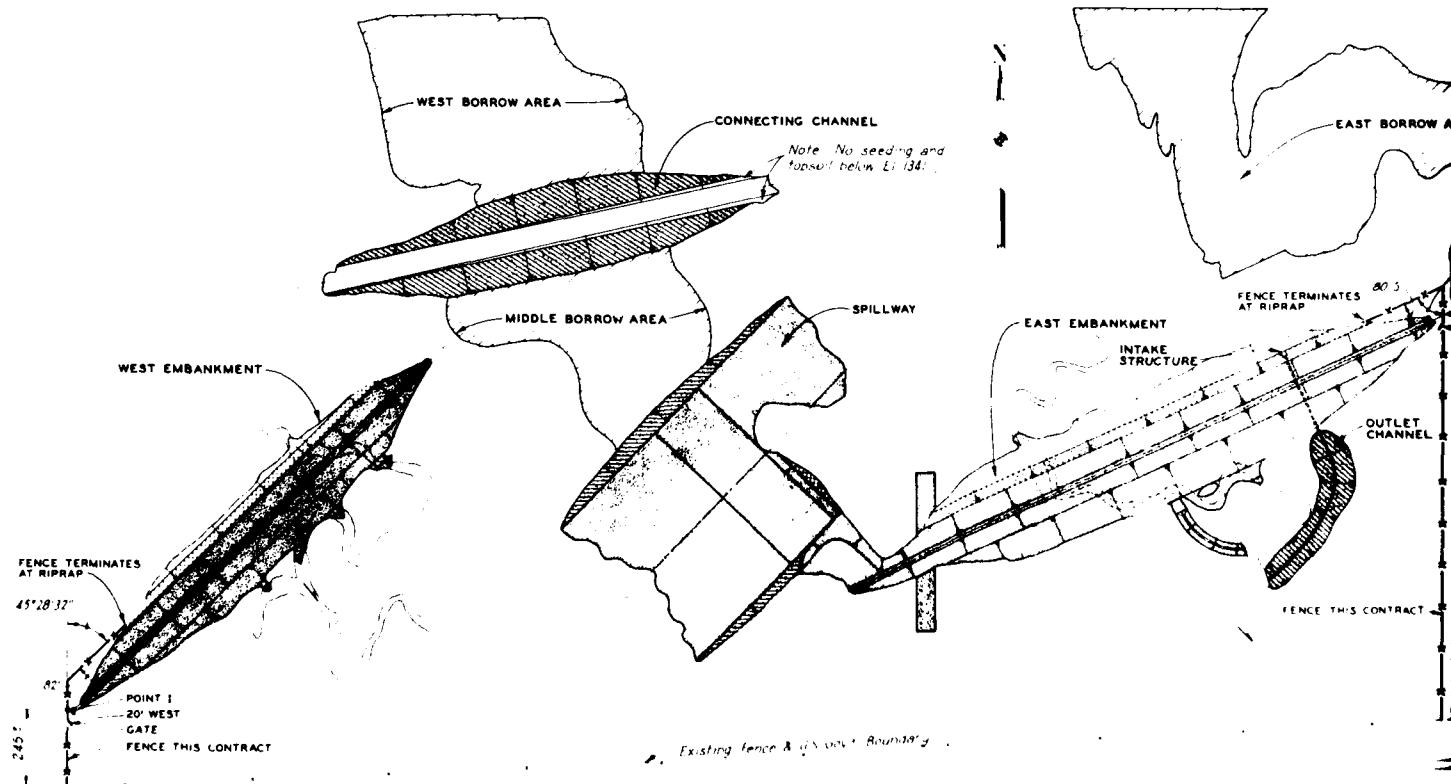
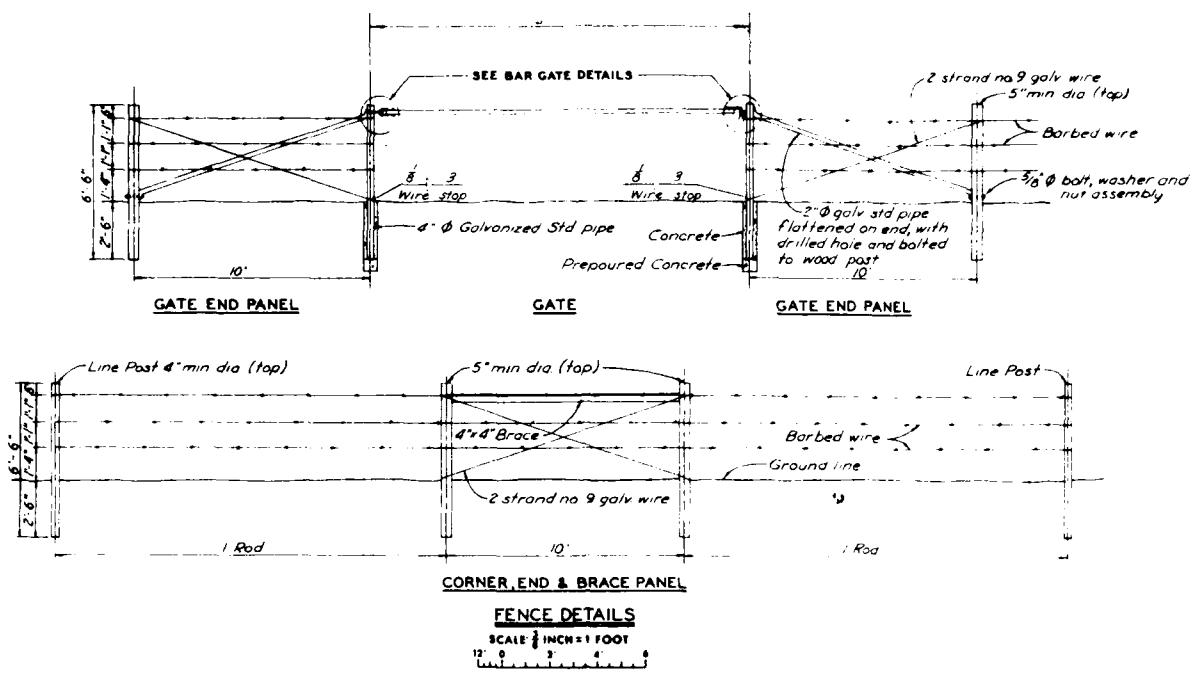


THIS PLAN ACCOMPANIES CONTRACT NO.
DA-28-006-85-98 MODIFICATION NO.

GENERAL NOTES

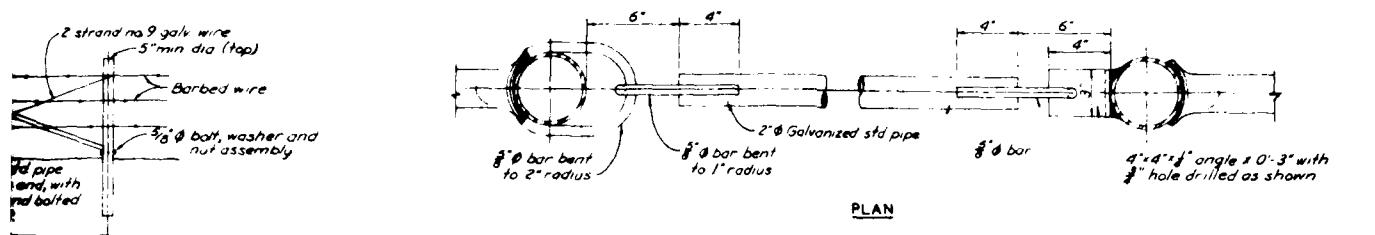
1. All elevations shown refer to feet above M.S.L.
1954 General Adjustment.
 2. For location of drain profiles see drawing 310E3 & 310E4

CORPS OF ENGINEERS

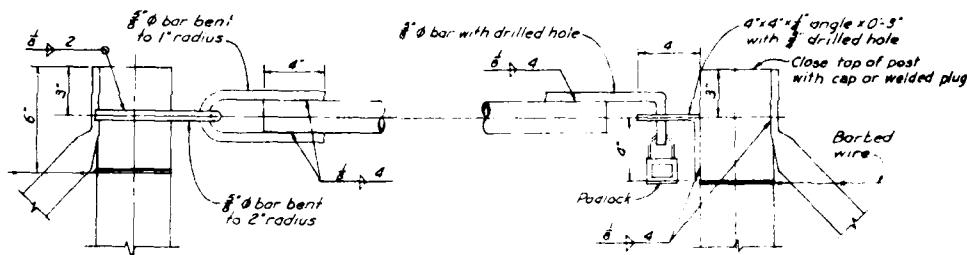
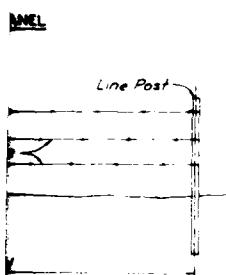


SLOPE PROTECTION AND FENCING PLAN

SCALE 1 INCH = 100 FEET



PLAN

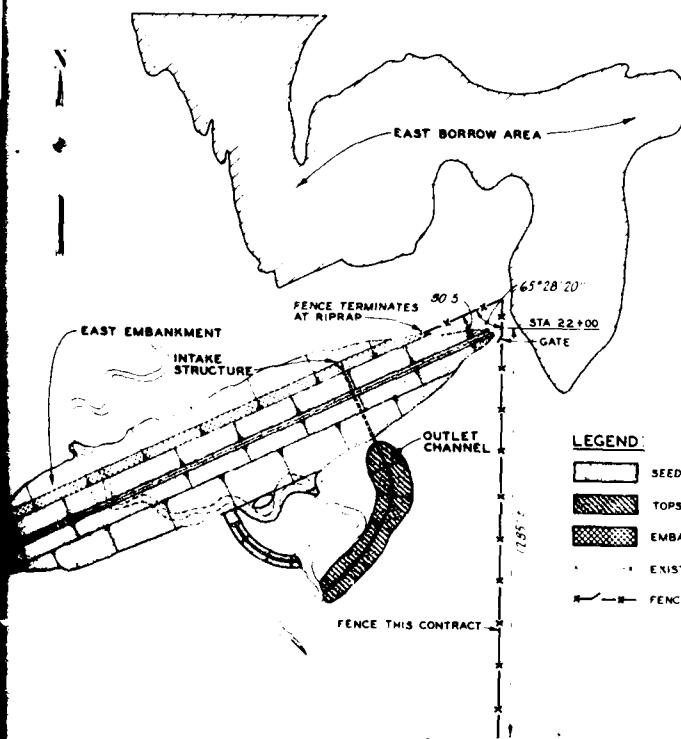


ELEVATION

BAR GATE DETAILS

SCALE 3 INCHES = 1 FOOT

0 3' 6' 9' 12'

GENERAL NOTES:

- All areas disturbed by grading under this contract except the borrow areas and topsoil stockpiles shall be seeded. Disturbed areas upstream and below El. 1341 shall not be seeded. Areas disturbed by the contractor outside the above indicated areas for which approval has not been secured, shall be seeded by and at the expense of the contractor.
- At site 9 shown on the location plan, move the existing gate located south east of the spillway to a new location south of the spillway as directed. Restore fence where gate is removed.

THIS DRAWING HAS BEEN RELEASED PURSUANT TO THE USA PATRIOT ACT

2-2-86 REVISED TO SHOW AS BUILT CONDITIONS

DATE: 10/16/86

REVISION: 1

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

DESIGNED BY: J. W. K.
DRAWN BY: C. H. M.
CHECKED BY: C. H. M.
APPROVED BY: P. K. K.
SALT CREEK AND ITS TRIBUTARIES, NEBRASKA
DAM AND RESERVOIR, SITE 13
SLOPE PROTECTION & FENCING PLAN
AND FENCING DETAILS

APPROVED: Charles T. Higby
CHIEF ENGINEERING DIVISION
U. S. ARMY CORPS OF ENGINEERS
OCT 1986

SIGNED: Harold J. Haas

CHIEF ENGINEERING DIVISION

U. S. ARMY CORPS OF ENGINEERS

OCT 1986

MSCL0-310E91

1082

PLATE A

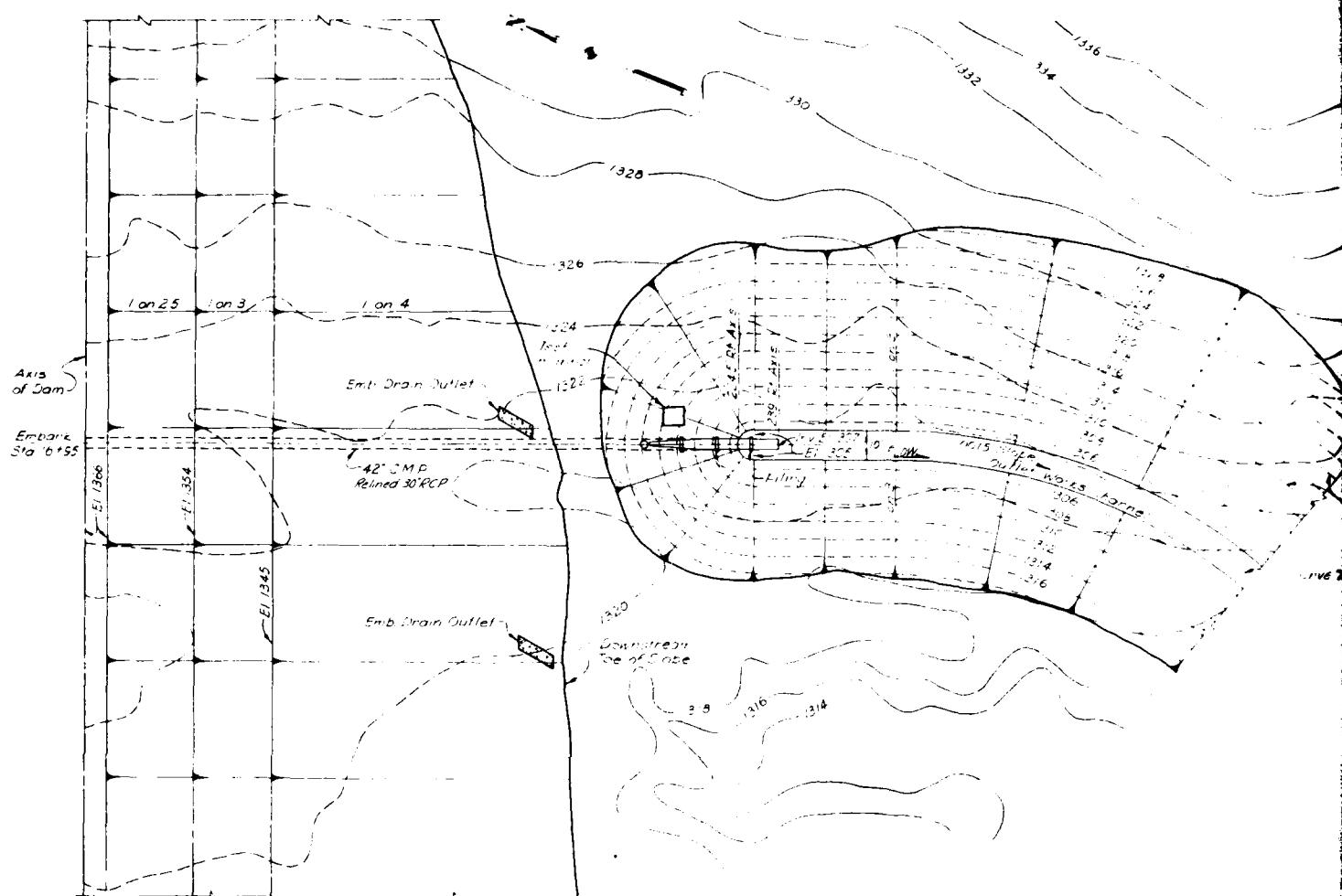
THIS PLAN ACCOMPANIES CONTRACT NO.
DA-25-100A-1, 85-96
MODIFICATION NO. 1

EMBANKMENT CRITERIA AND PERFORMANCE REPORT

1082

PLATE A

CORPS OF ENGINEERS



OUTLET GRADING DETAIL

SCALE 1 INCH = 20 FEET

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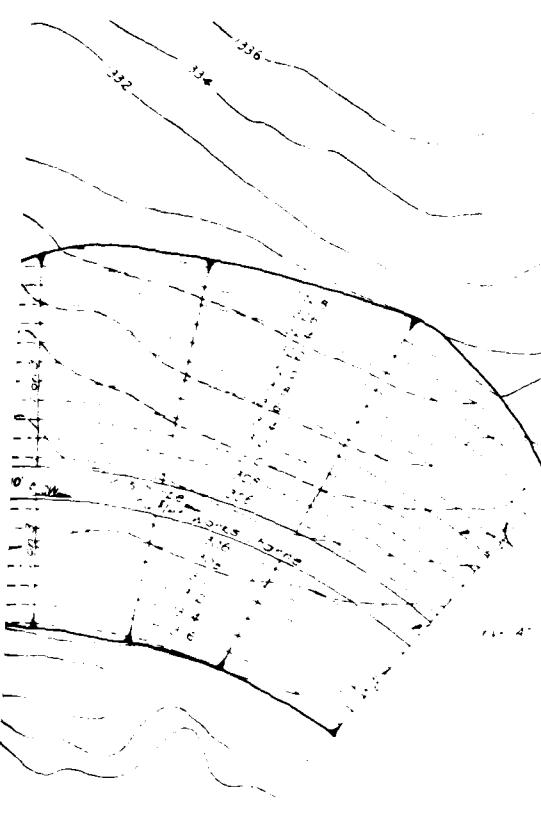
5. 2. 2

Almond-flavored Mousse Supreme

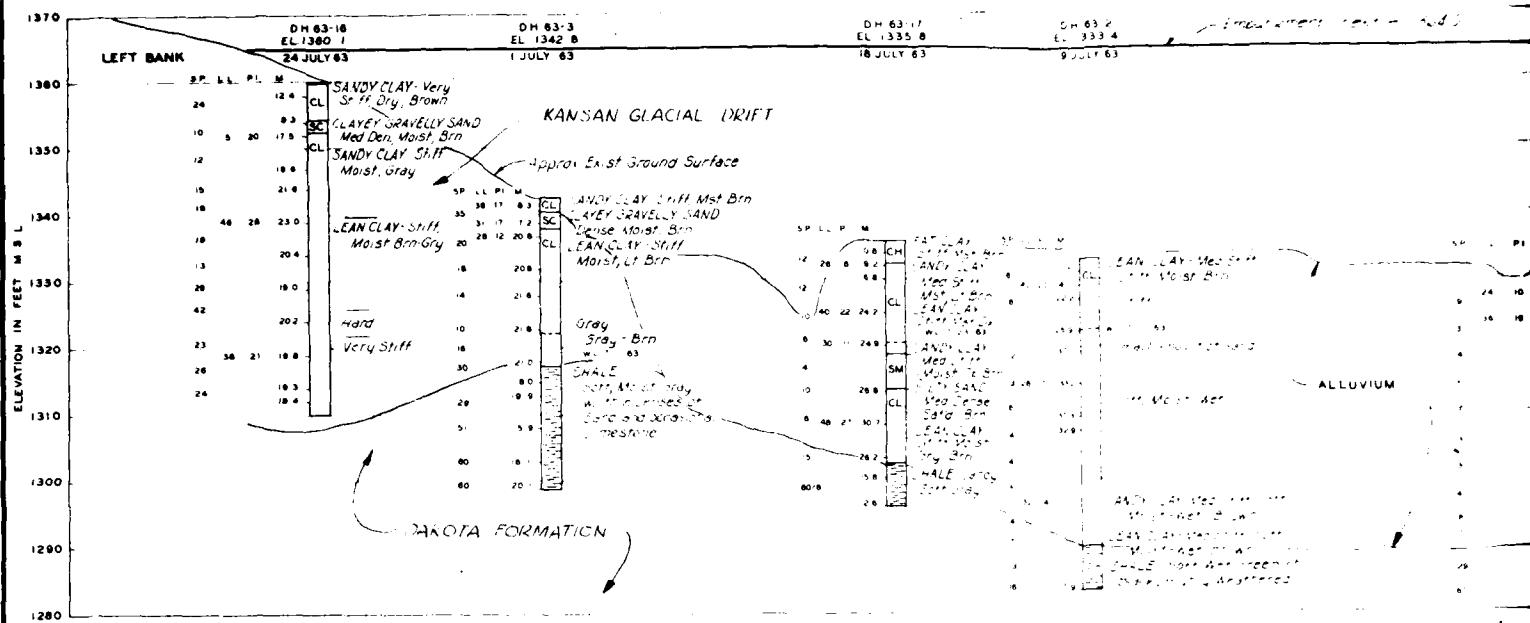
100-10

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U. S. ARMY



CORPS OF ENGINEERS



VALLEY SECTION AT WEST EMBANKMENT

SCALE VERT : NM = FEET
HORIZ : NM = FEET

BORING LEGEND

H.A. 64-1

15 MA 64

0
10
20

DEPTH IN FEET

SILTY CLAY
Silt, 1/2 st. Dr Brn
EAT, CLAY
Med Stiff, Moist Brn
+ Brown
Increase in Moisture
Soft

H.A. 64-2

15 MAY 64

0
10
20

DEPTH IN FEET

SILTY CLAY
Med Stiff, Mois., Cr. Brn.
EAT, EAT
Med Stiff, 1/2 st. Dr Brn
SILTY CLAY
Med Stiff, Mois., Cr. Brn.
EAT, CLAY
Med Stiff, 1/2 st. Dr. Brn.

WEST EMBANKMENT LEFT ABUTMENT AREA

DEPTH IN FEET

Depth (ft)	Geological Unit
0 - 19.5	LEAN CLAY Med. Stiff Mst, Brn; CANDY CLAY Med Stiff Mst, Gry-Brn. LEAN CLAY Med. Stiff Mst, Lt Brn LEAN CLAY Med. Stiff Mst, Msh, Gry-Brn.
19.5 - 24.5	L. B. 1000 Med Stiff Mst, Gry-Brn.

EAST BORROW AREA

CLASSIFICATION OF SOILS:

CH	FAT CLAY
CL	LEAN CLAY, SANDY CLAY
ML	SANDY SILT
SC	CLAYEY SAND, CLAYEY GR.
SM	SILTY SAND
CL	SILTY CLAY, SANDY CLAY
ML	

DH 63-2
EL 1334.0
3 JULY 63DH 63-1
EL 1334.0
3 JULY 63DH 63-18
EL 346.2
22 JULY 63DH 63-19
EL 1358.0
23 JULY 63

1370

RIGHT BANK

KIA-SAN IN ALUVIAL CREEK

Bottom of cut around 1370 ft

SPLIT RIVER

1345 Clay, Stiff, Gray

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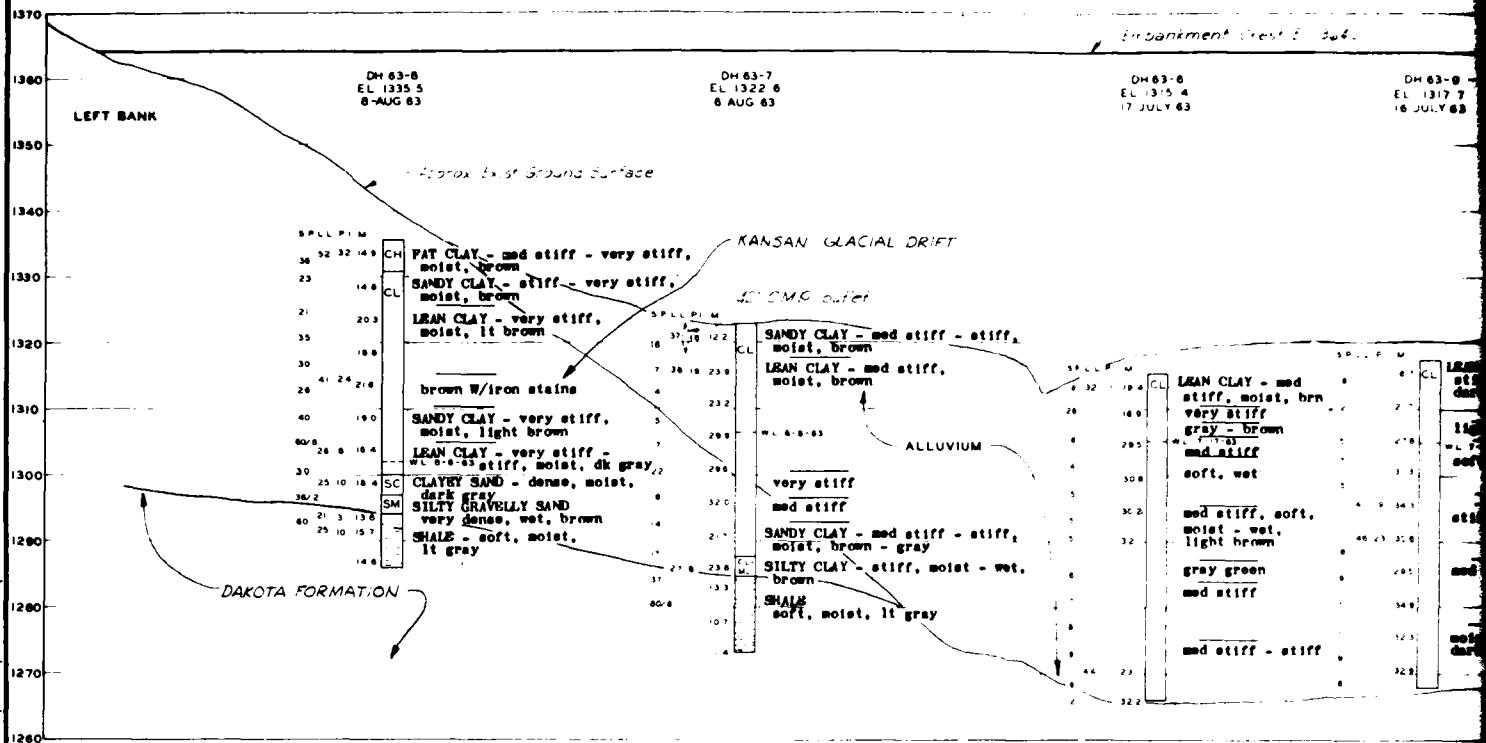
1495

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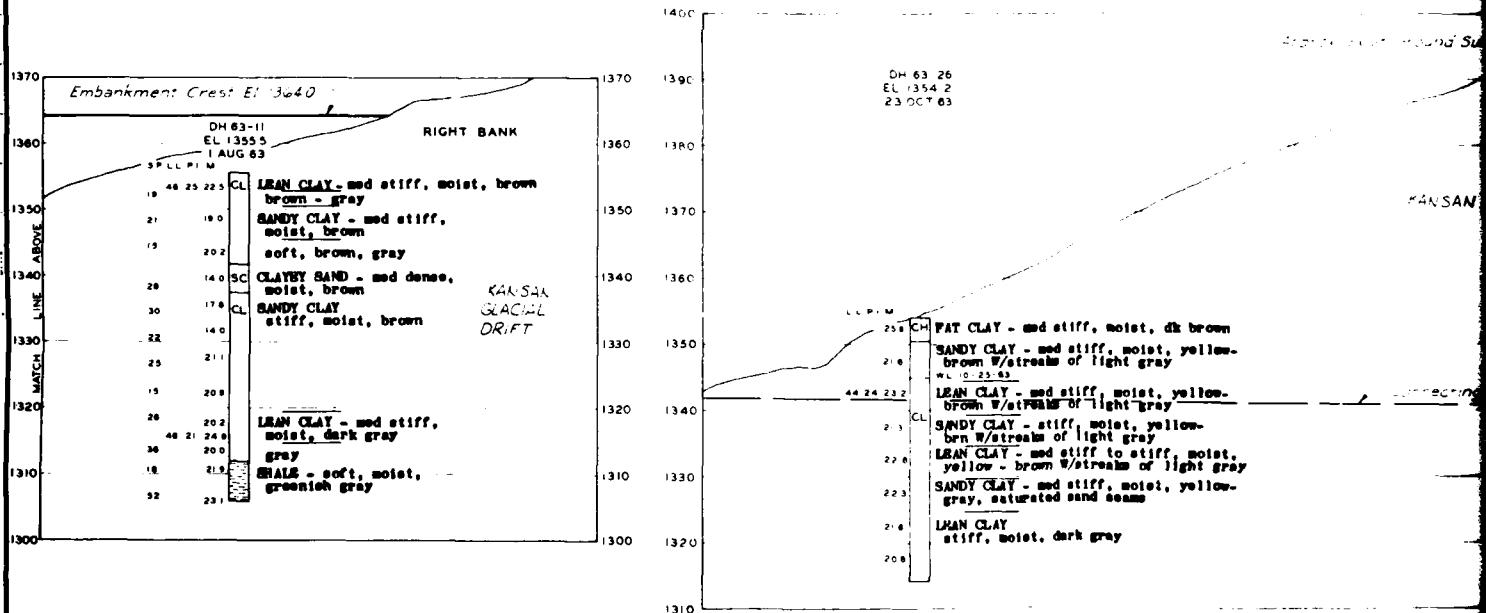
1496

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CORPS OF ENGINEERS



VALLEY SECTION AT EAST EMBANKMENT

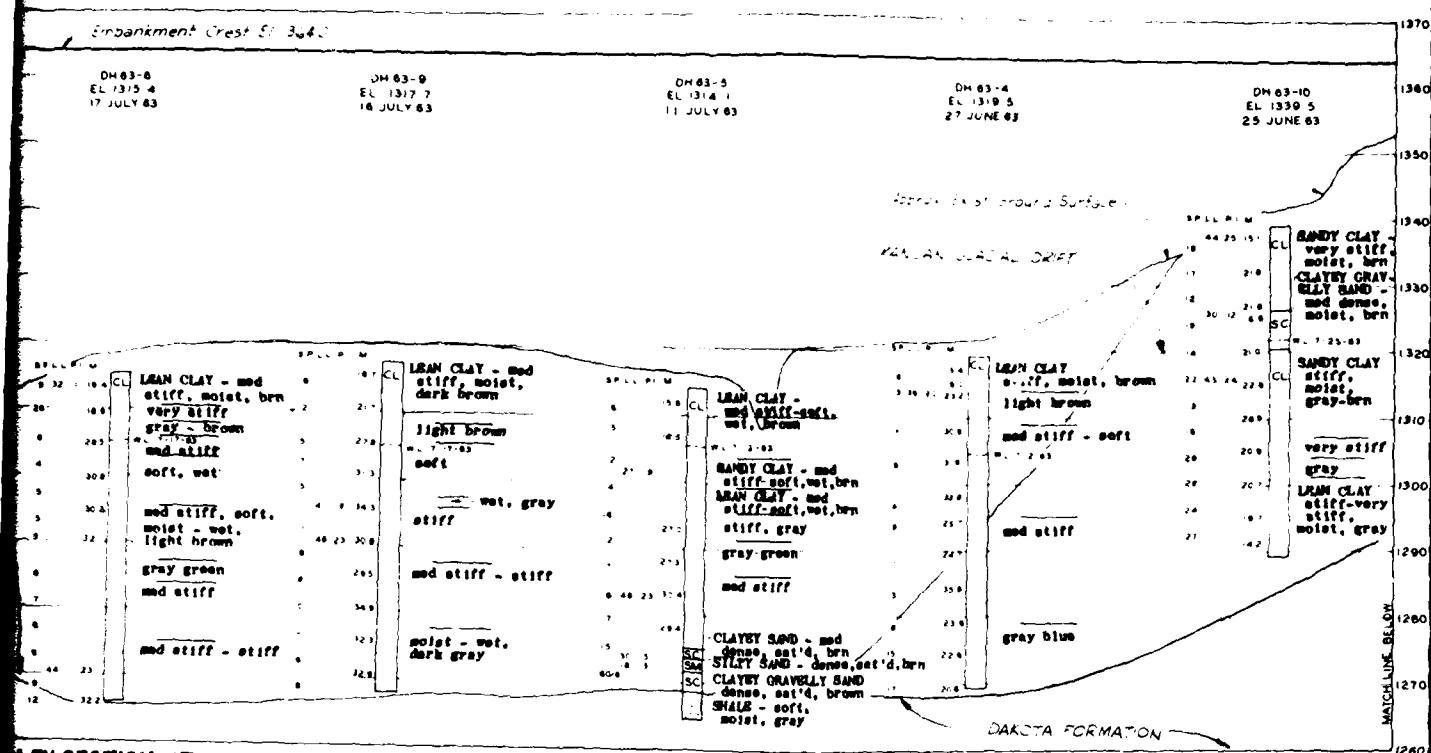


CONNECTING

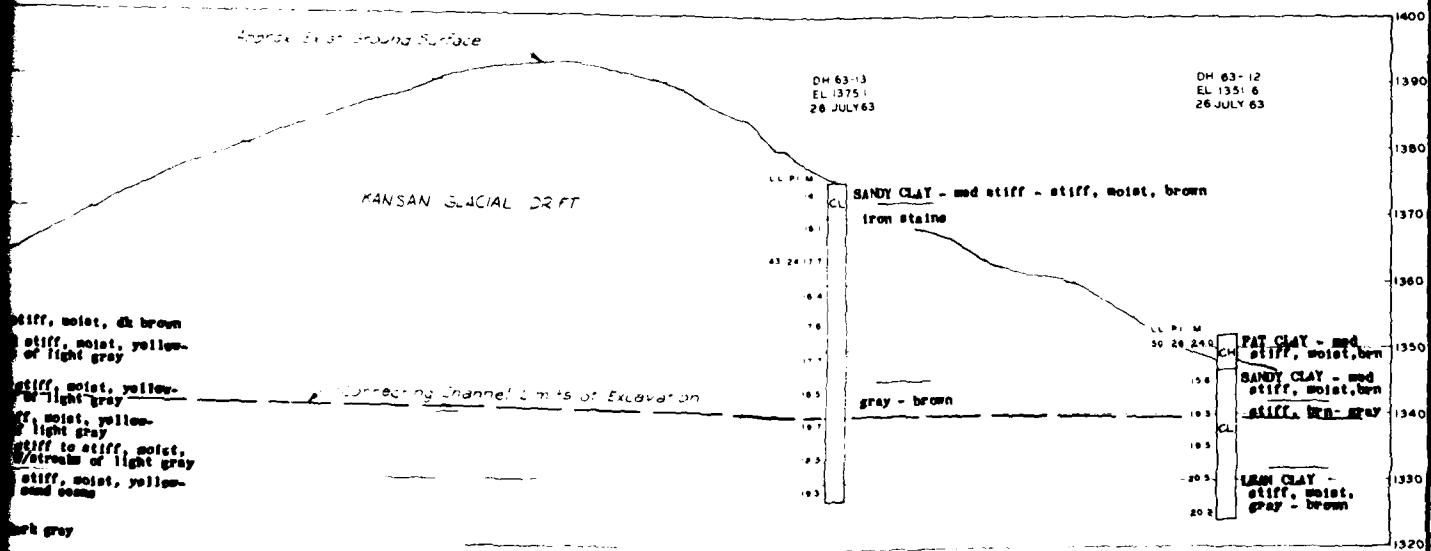
GENERAL NOTES.

1. All elevations shown refer to feet above M.S.L., 1954 General Adjustment.
 2. For Boring Legend, Classification of Soil and notes, see dug. 3108M1.
 3. For location of Boreings, see dug. 3108S & 3108M.

U. S. ARMY



LEY SECTION AT EAST EMBANKMENT



CONNECTING CHANNEL AREA BORINGS

GENERAL NOTES

1. All elevations shown refer to feet above
N.S.L., 1954 General Adjustment.
 2. For Boring Legend, Classification of Soils
and notes, see dug. 310811.
 3. For location of Borings, see dug. 310834 & 31084.

SCALE VERT. 1 INCH = 10 FEET
HORIZ 1 INCH = 50 FEET



DATE	DESCRIPTION	NAME	APPROV.
	REVISIONS		
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
SUPERVISOR BY: V.E.G. REMOVED BY: R.L.W. TRANSferred BY: R.L.W. REMOVED BY: L.J.S. <i>John F. Kline, Inc.</i>	SALT CREEK AND ITS TRIBUTARIES, NEBRASKA DAM AND RESERVOIR, SITE 13 RECORD OF BORINGS SHEET 2		
APPROVED <i>H. J. Hines</i> <i>Project Manager</i>	APPROVED <i>Charles P. Hipp</i>	DATE OCT 1964	
	NAME: AL SMITH	SP-100-100-000	
	TELETYPE NUMBER		
	MSCI 10-310E12		

THIS DRAWING HAS BEEN REDUCED TO
ONE-HALF THE ORIGINAL SCALE.

THIS PLAN ACTUALLY
DA-22-086-^{mg}

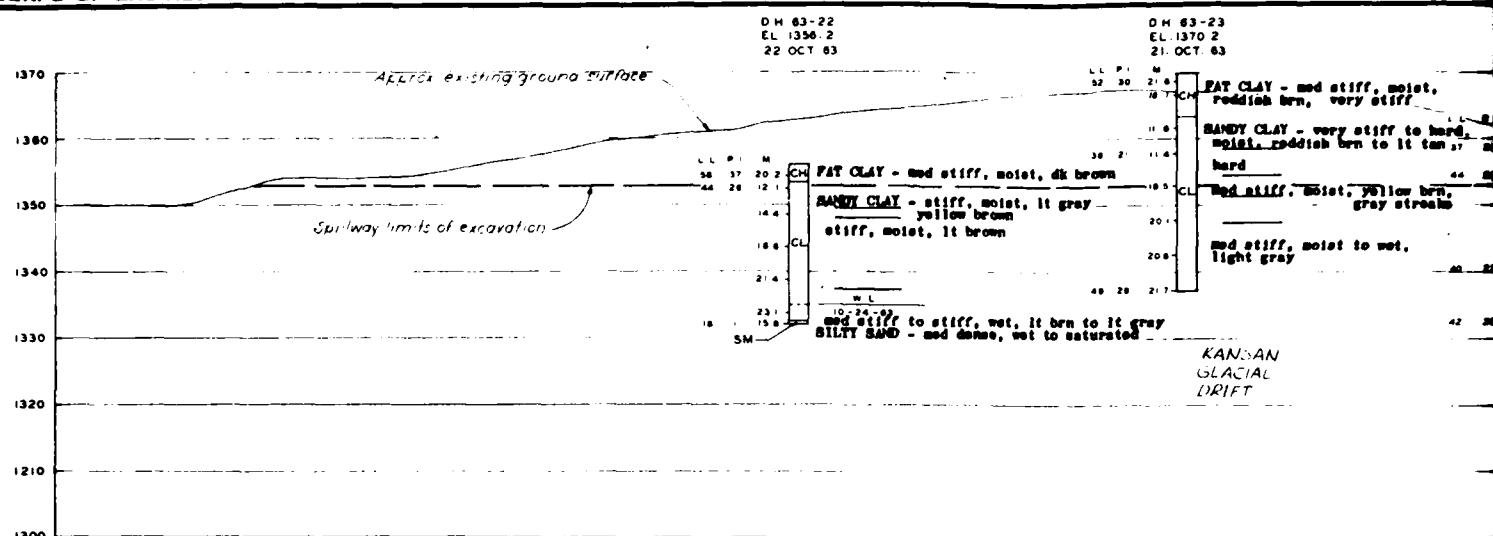
EMBANKMENT CRITERIA AND PERFORMANCE REPORT

(1982)

(1982) PLATE

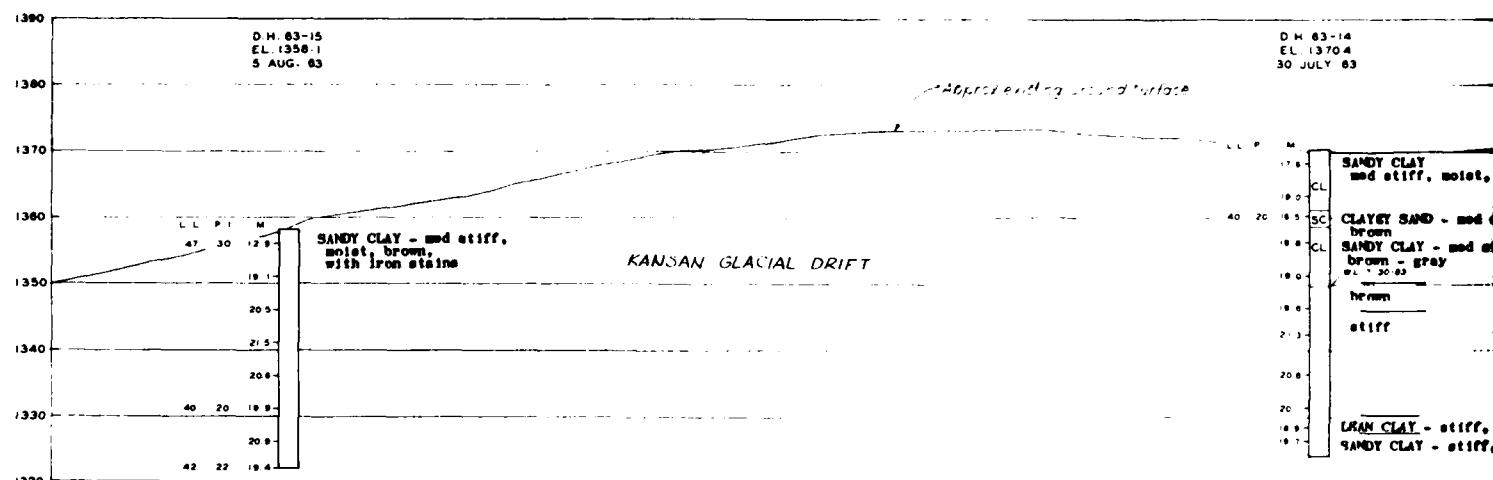
PLATE A-12

CORPS OF ENGINEERS



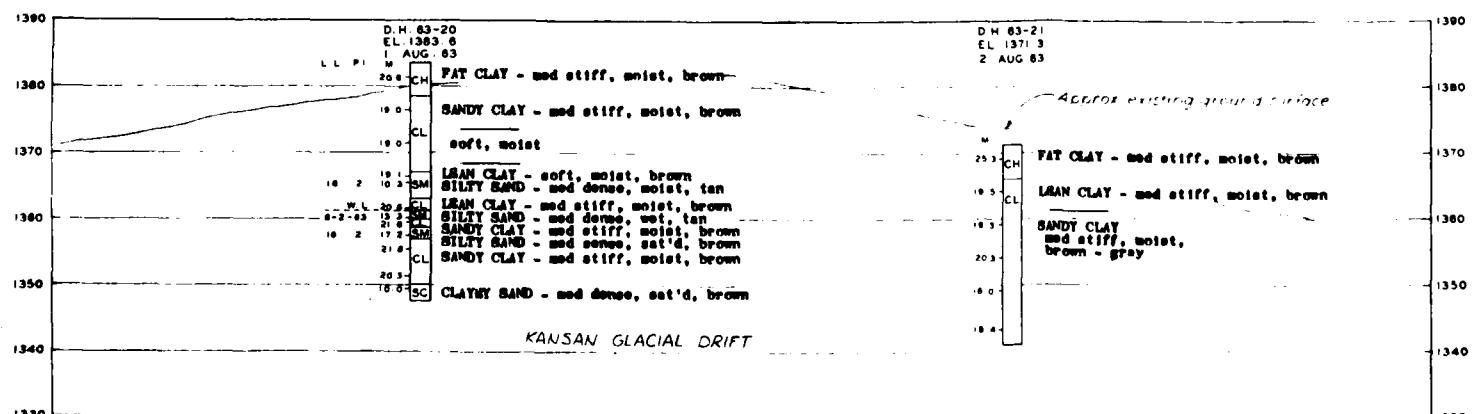
SPILLWAY AREA BORINGS

SCALE: VERT 1 INCH=10 FEET
HORIZ 1 INCH=20 FEET



WEST BORROW AREA

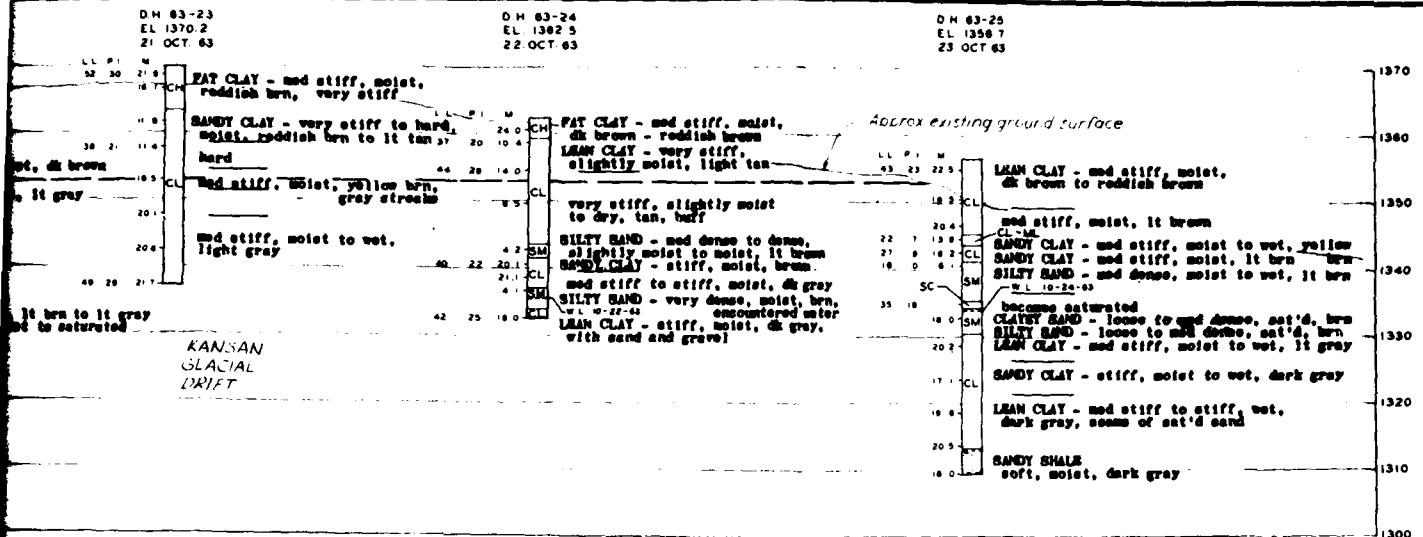
SCALE: VERT 1 INCH=10 FEET
HORIZ 1 INCH=20 FEET



MIDDLE BORROW AREA

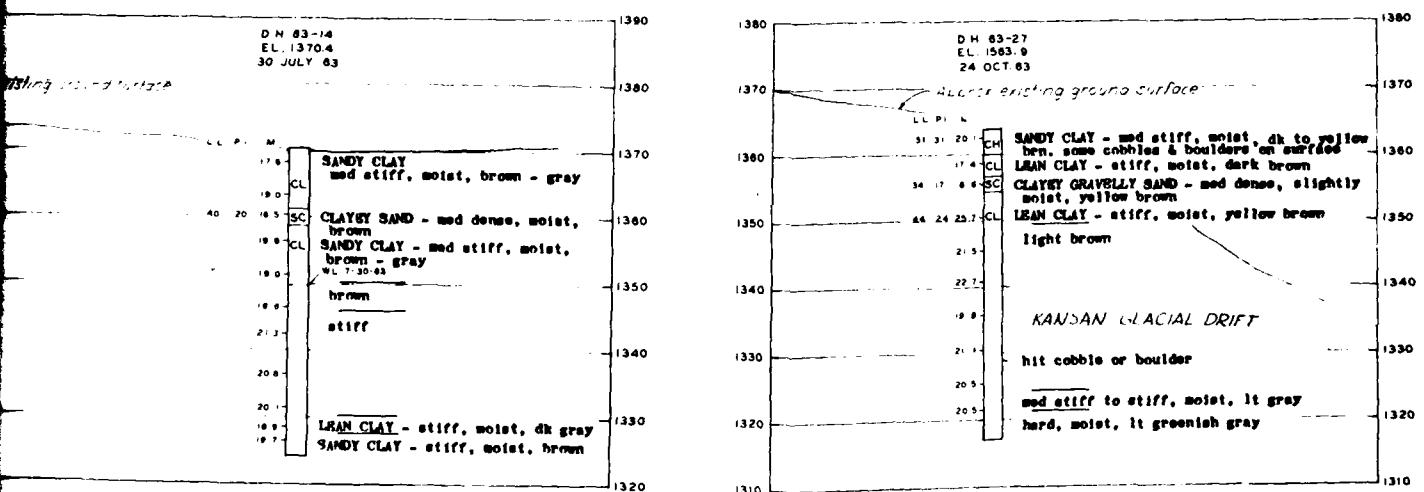
SCALE: VERT 1 INCH=10 FEET
HORIZ 1 INCH=50 FEET

U. S. ARMY



SPILLWAY AREA BORINGS

SCALE: VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 20 FEET

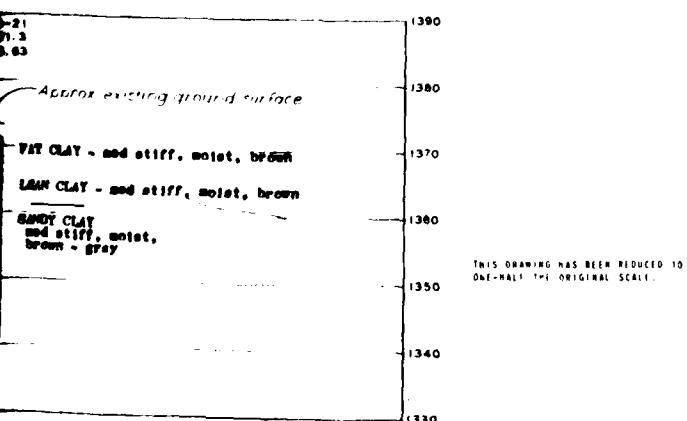


EAST BORROW AREA

SCALE VERT. 1 INCH = 10 FEET
HORIZ. 1 INCH = 50 FEET

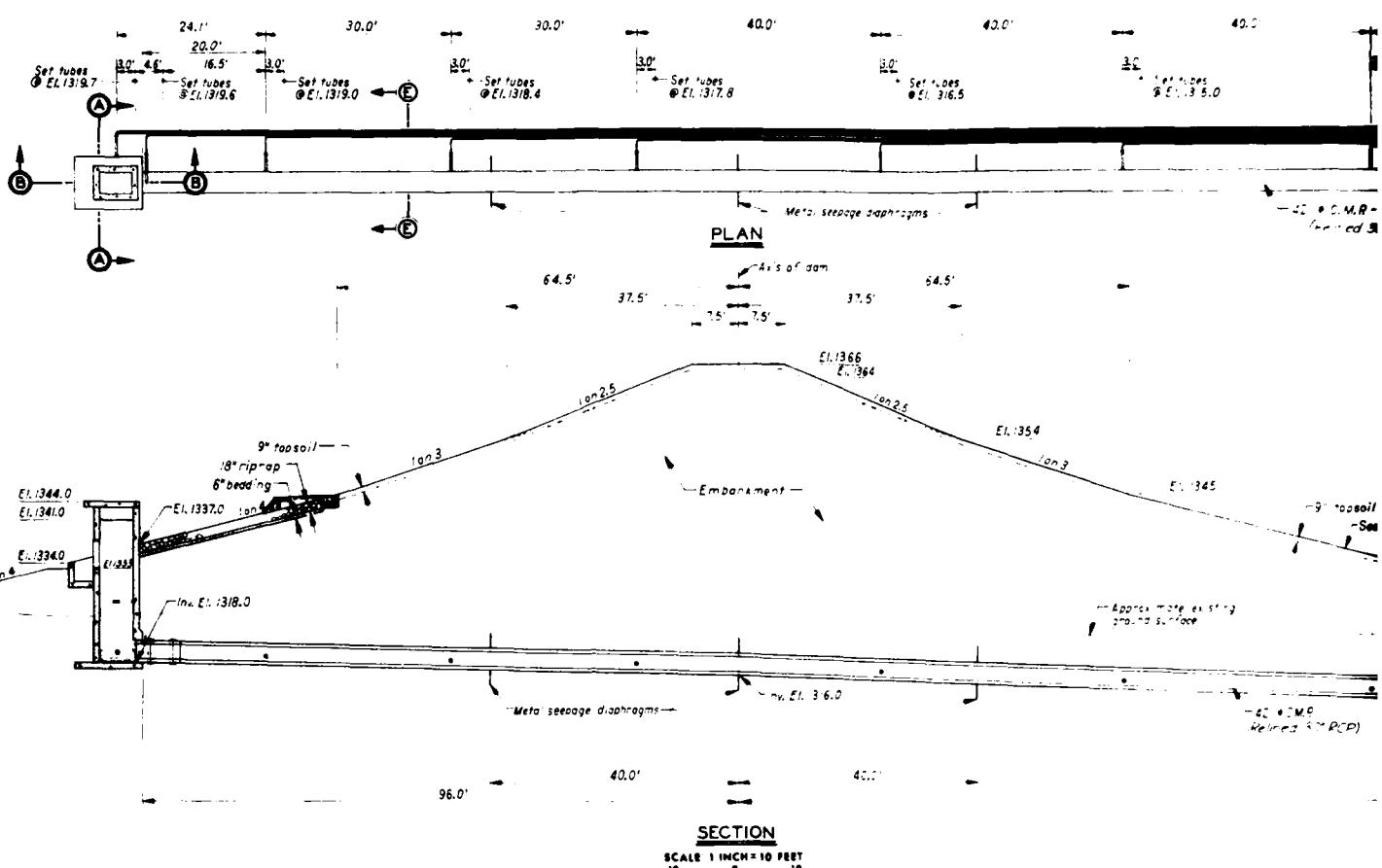
GENERAL NOTES:

1. All elevations shown refer to feet above M.S.L., 1954 General Adjustment.
2. For Boring Legend, Classification of Soils and Notes, see dwg. 310811.
3. For location of borings, see dwg. 31083 & 31084.

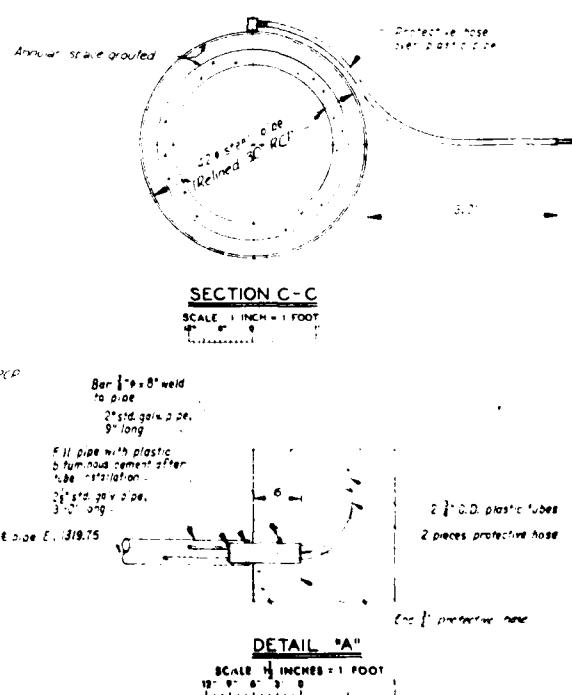
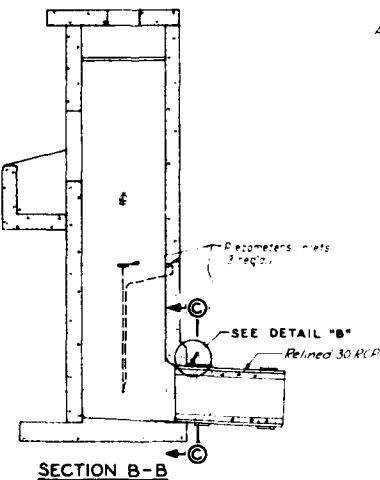
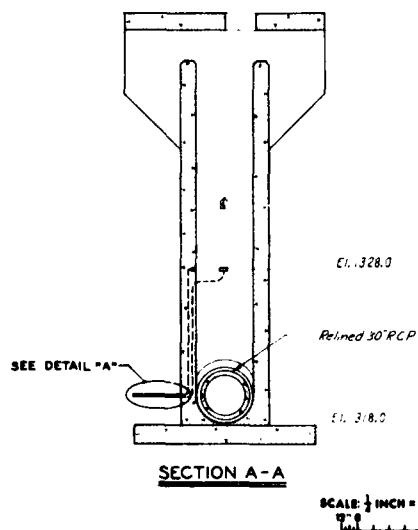


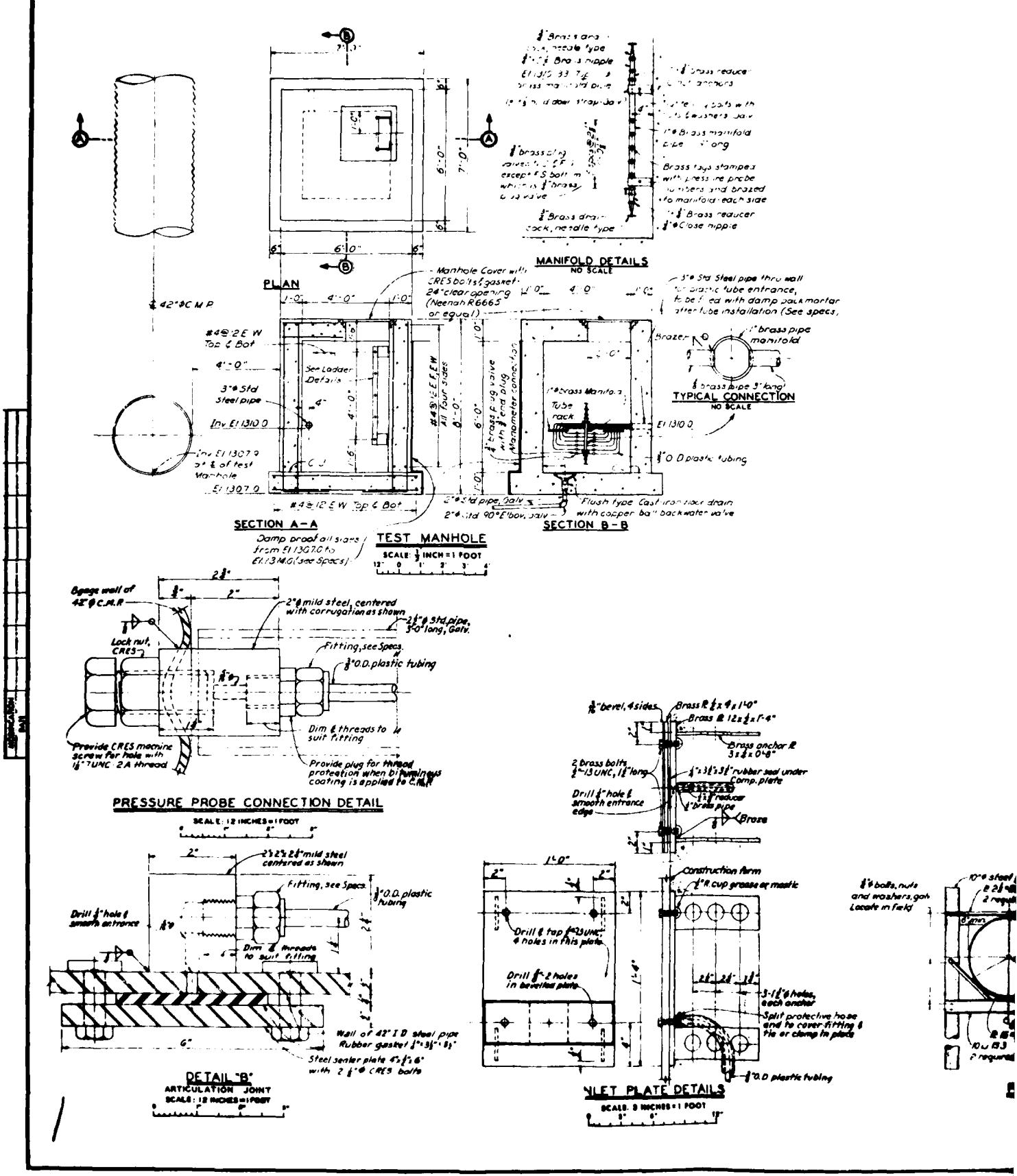
THIS PLAN ACCOMPANIES CONTRACT NO.
DA-29-066-m. MODIFICATION NO.

CORPS OF ENGINEERS



MONITORING
DATA





CORPS OF ENGINEERS

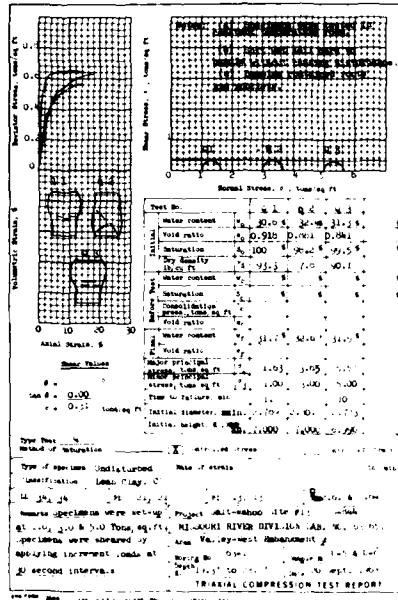


FIGURE 1

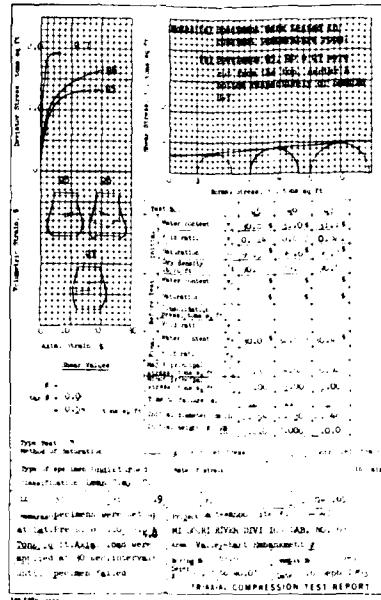


FIGURE 3

CHURCHES 813

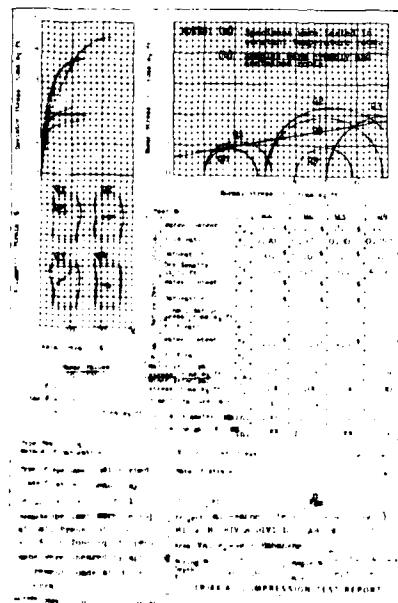


FIGURE 2

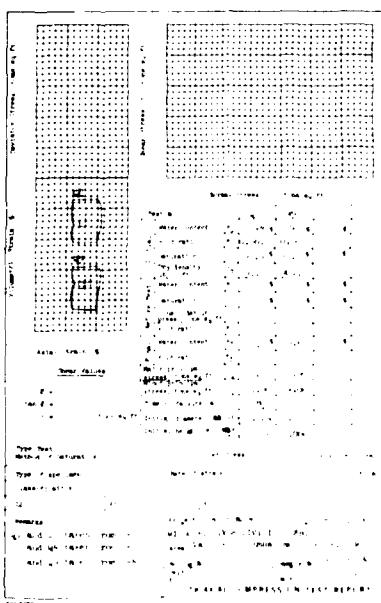


FIGURE 4

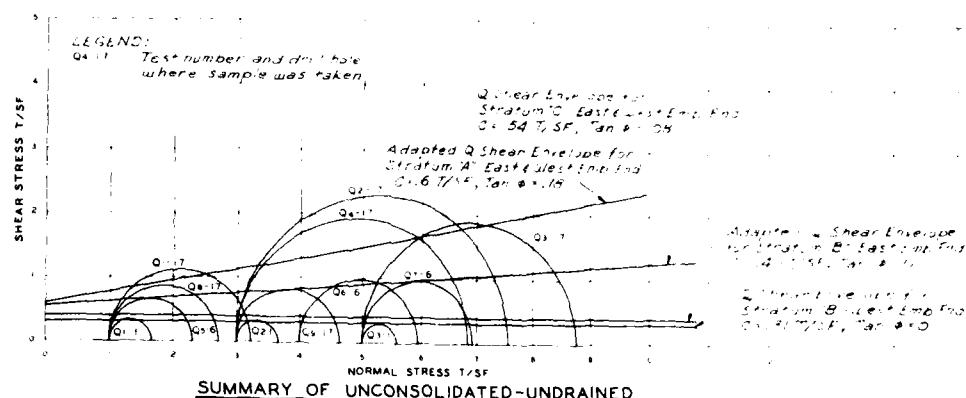


FIGURE 5

THIS PAGE HAS BEEN REDUCED TO
SIZE 8 1/2 X 11 INCHES BY THE ORIGINAL SCANNER.

DATE	DESCRIPTION	MADE	APPR.
	U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA	SALT CREEK AND ITS TRIBUTARIES, NEBRASKA	
REQ'D BY	DAM AND RESERVOIR, SITE 13		
DRAWN BY	FOUNDATION SOIL TEST DATA		
CHECKED BY	UNCONSOLIDATED-UNDRAINED (Q)		
APPROVED BY <i>John C. C. District Engineer</i> CIVIL ENGINEER	APPROVED	DATE	APR. 1964
APPROVED <i>John C. C. District Engineer</i> CIVIL ENGINEER	APPROVED	DATE	APR. 1964
APPROVED	SCALE 1:20,000	MAP NO. 100-200-000	RECORDED NUMBER
<i>Approved by John C. C. District Engineer</i> COL. C. C. DISTRICT ENGINEER	SHEET 1		

THIS PLAN ACCOMPANIES CONTRACT NO.
DA-25-066-^{mg} MODIFICATION NO.

CORPS OF ENGINEERS

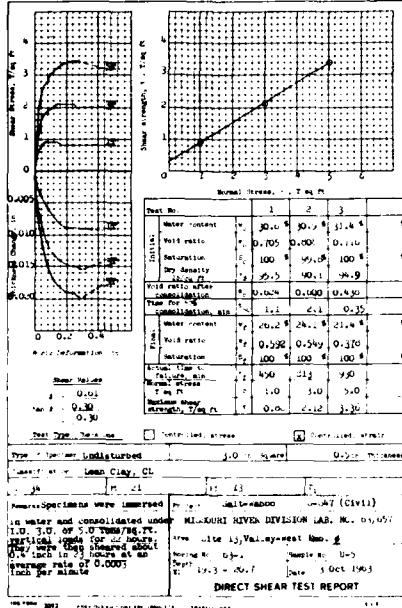


FIGURE 1

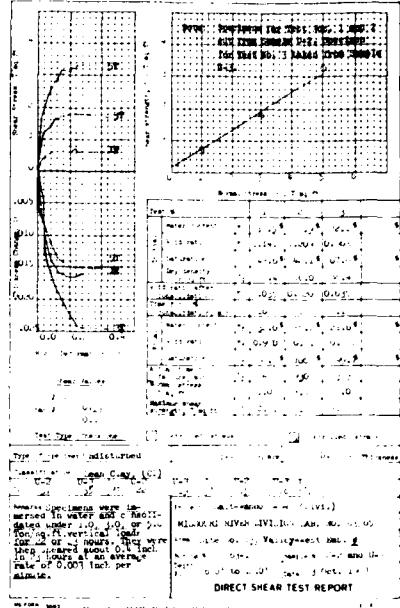


FIGURE 2

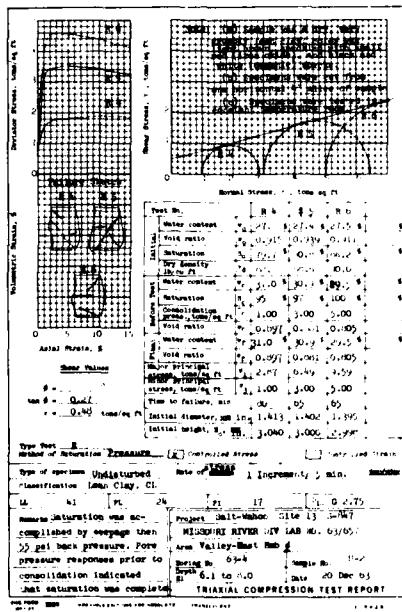


FIGURE 5

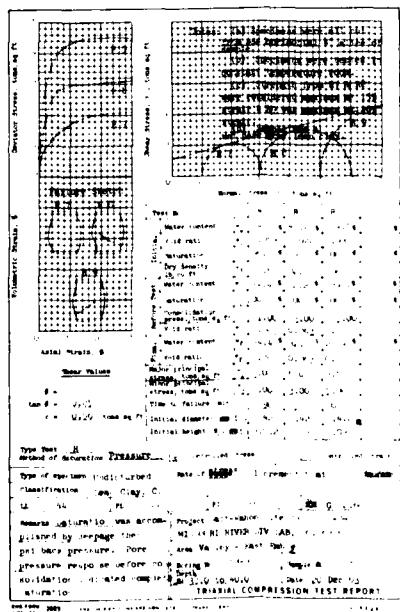


FIGURE 6

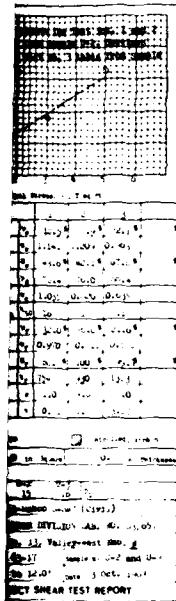


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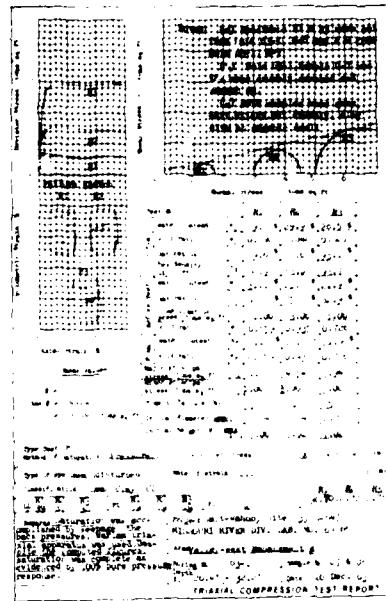


FIGURE 4

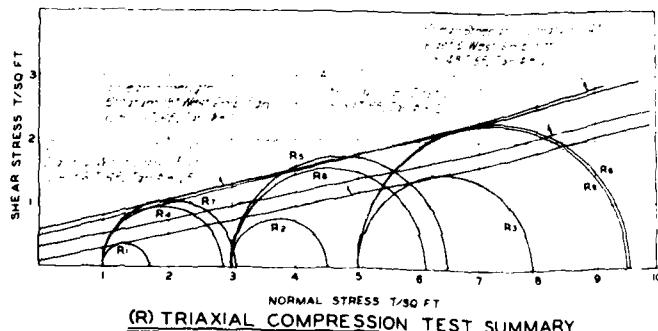


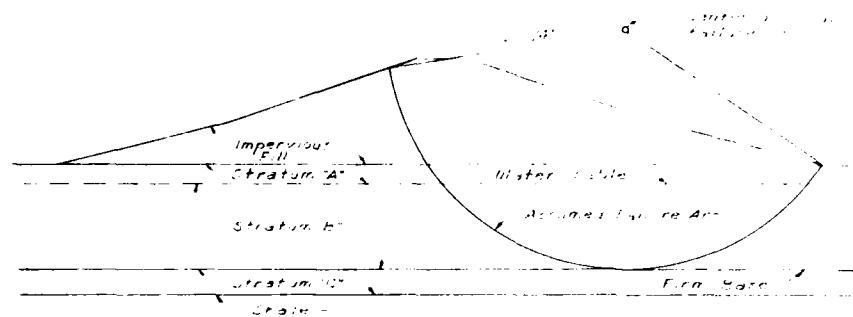
FIGURE 7

THIS DRAWING HAS BEEN REDUCED TO
ONE-HALF OF ITS ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPROVED
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
DAM AND RESERVOIR, SITE 13 FOUNDATION SOIL TEST DATA DIRECT SHEAR AND CONSOLIDATED-UNDRAINED SHEAR TESTS			
Charles E. Foy		Date: Jan 1964	DAE-13-100-20-00
Howard W. Clark		Date: 1/14/64	DAE-13-100-20-00
		RECEIVED	RECORDED

THIS PLAN ACCOMPANIES CONTRACT NO.
DA-38-068-
MODIFICATION NO.

CORPS OF ENGINEERS



STABILITY ANALYSIS - CIRCULAR ARC METHOD

FINITE SLICES - WEST EMBANKMENT - END OF CONSTRUCTION

SCALE 1 INCH=20 FEET

WEST EMBANKMENT STABILITY ANALYSIS DATA ADOPTED DESIGN VALUES					
Material	Density-Tons/Cu. Ft.	Shear Strength			
	Moist	Sat'd.	Bouss	Tan ϕ	Coh-T/SF
Embankment	.060			.15	.80
Stratum "A"	.053			.18	.60
Stratum "B"	.0585	.0273		0	.31

LEGEND:

N = Normal Force
T = Tangential Force
L = Length of arc through subject material
C = Unit cohesion of material along arc

CALCULATIONS:

ΣN Embankment = 5.8 Tons
 ΣN Stratum "A" = 1.2 Tons
L Embankment = 34 Feet
L Stratum "A" = 15 Feet
L Stratum "B" = 130 Feet
Cf = 50 Tons

$$F.S. = \frac{\Sigma N \tan \phi + \Sigma C}{\Sigma T}$$

$$(5.8x.15) + (1.2x.18) + (34x.8) + (15x.60) + (130x.31) = 50.0$$

$$F.S. = 1.57$$

EAST EMBANKMENT STABILITY ANALYSIS ADOPTED DESIGN					
Material	Density-Tons/Cu. Ft.	Moist	Sat'd.	B	
Embankment	.060				
Stratum "A"	.053				
Stratum "B"	.0585			.0585	

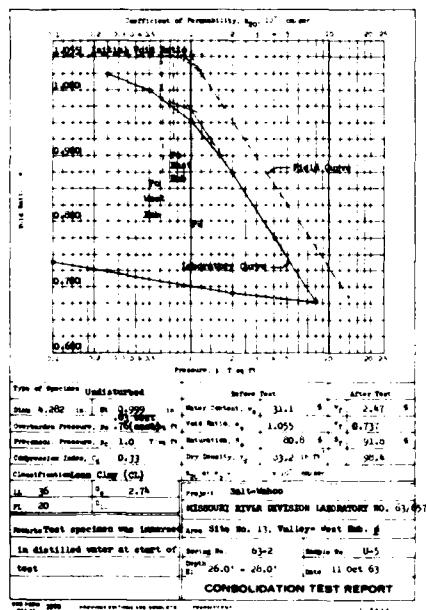


FIGURE 1

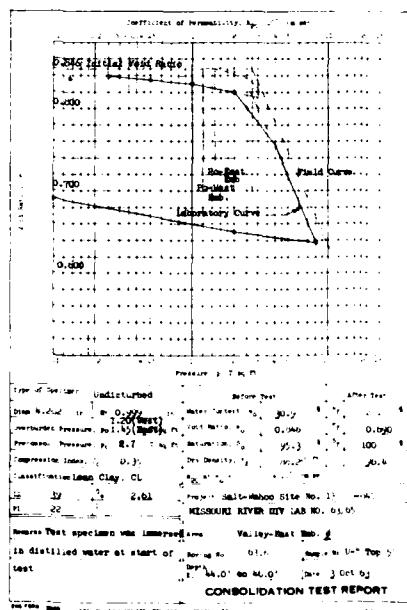
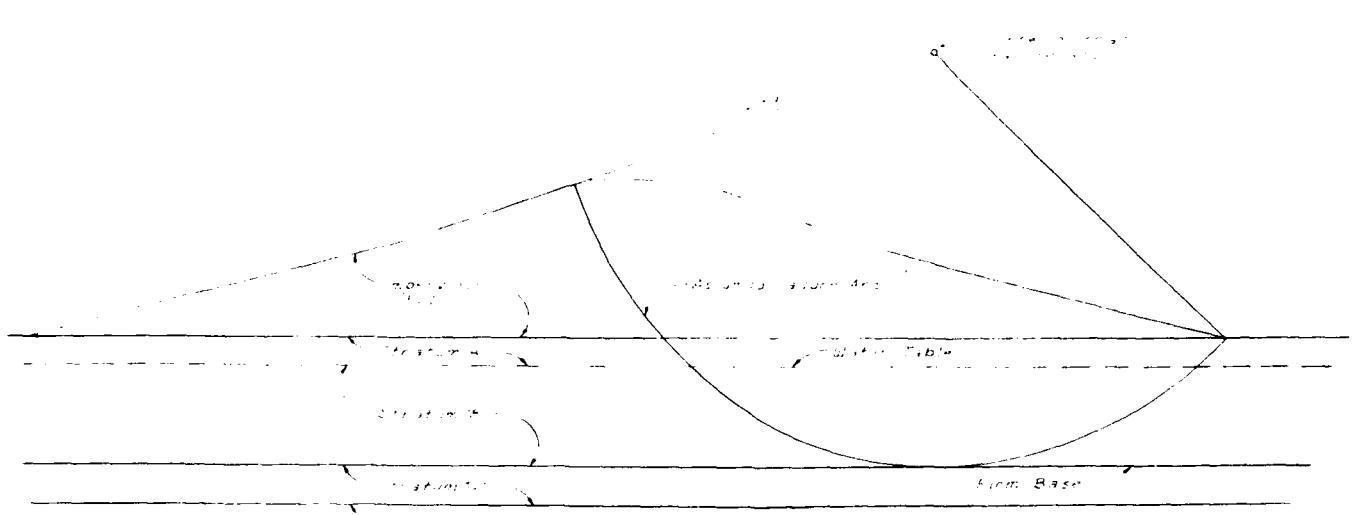


FIGURE 2

FIGURE



STABILITY ANALYSIS - CIRCULAR ARC METHOD
FINITE SLICES - EAST EMBANKMENT - END OF CONSTRUCTION
SCALE 1 INCH = 20 FEET

EAST EMBANKMENT STABILITY ANALYSIS DATA ASCRIBED DESIGN VALUES					
Material	Density-Tons/Cu. Ft.	Shear Strength			
Moist	Sat'd.	Bouyant	Tan ϕ	Coh-T/SF	
Embankment	.060		.15	.80	
Stratum "A"	.053		.18	.60	
Stratum "B"	.0585		0	.40	

LEGEND:

N = Normal Force
 T = Tangential Force
 L = Length of arc through subject material
 C = Unit cohesion of material along arc

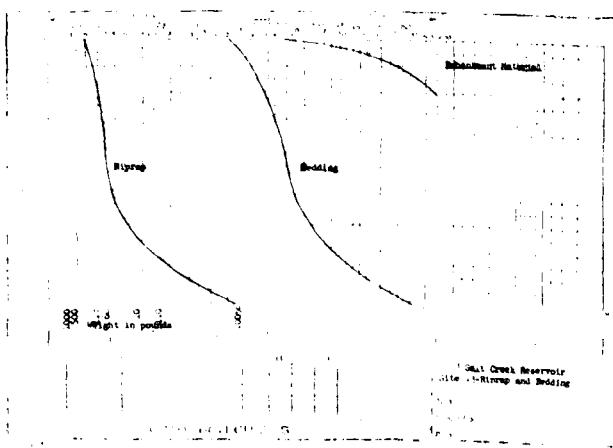
CALCULATIONS:

ΣN Embankment = 30.9 Tons
 ΣN Stratum "A" = 23.5 Tons
 L Embankment = 58 Feet
 L Stratum "A" = 27 Feet
 L Stratum "B" = 184 Feet
 ΣT = 108.2 Tons

$$F.S. = \frac{\Sigma N \tan \phi + \Sigma C L}{\Sigma T}$$

$$\frac{(30.9 \times .15) + (23.5 \times .18) + (58 \times .80) + (184 \times .4)}{108}$$

$$F.S. = 1.34$$



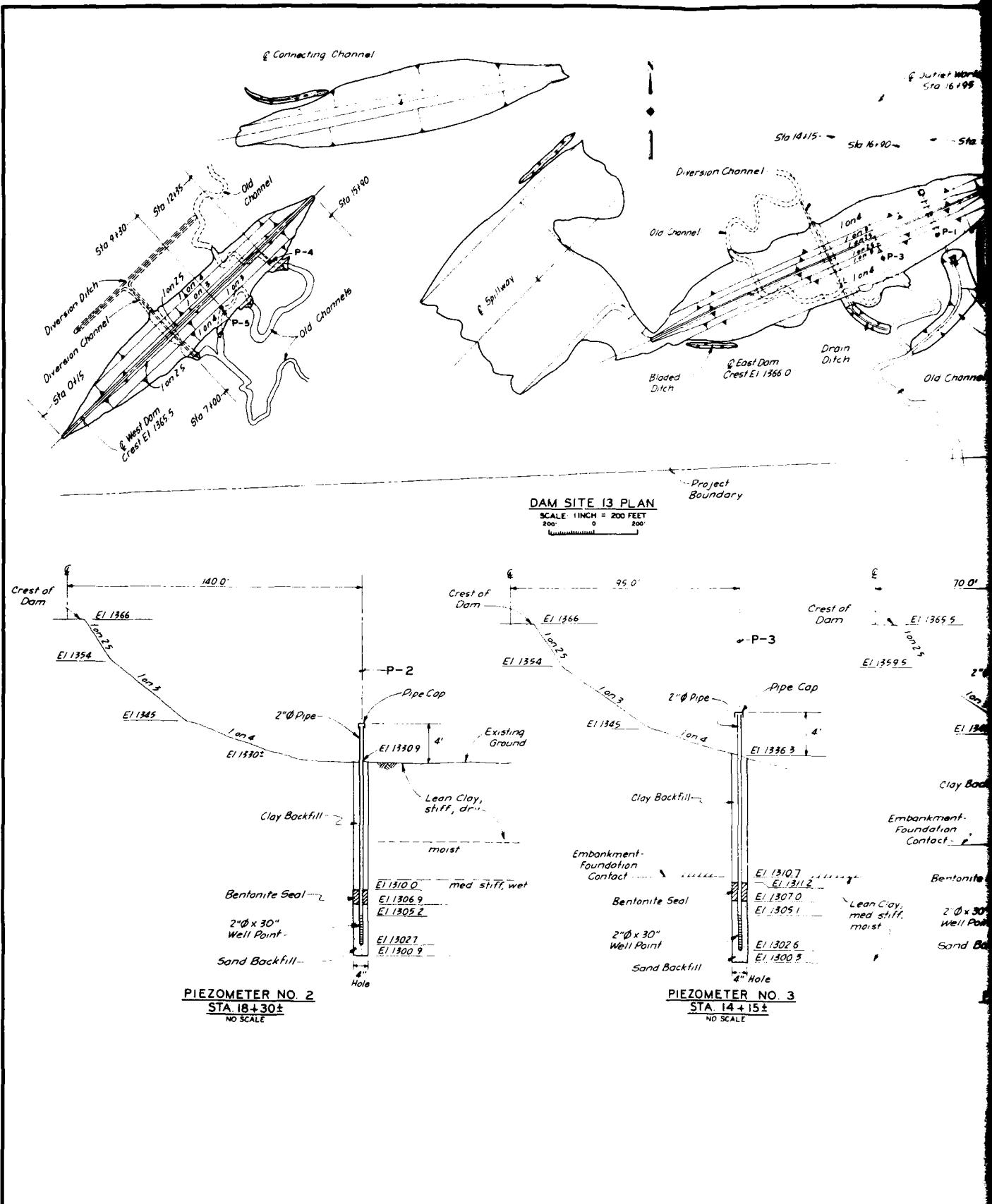
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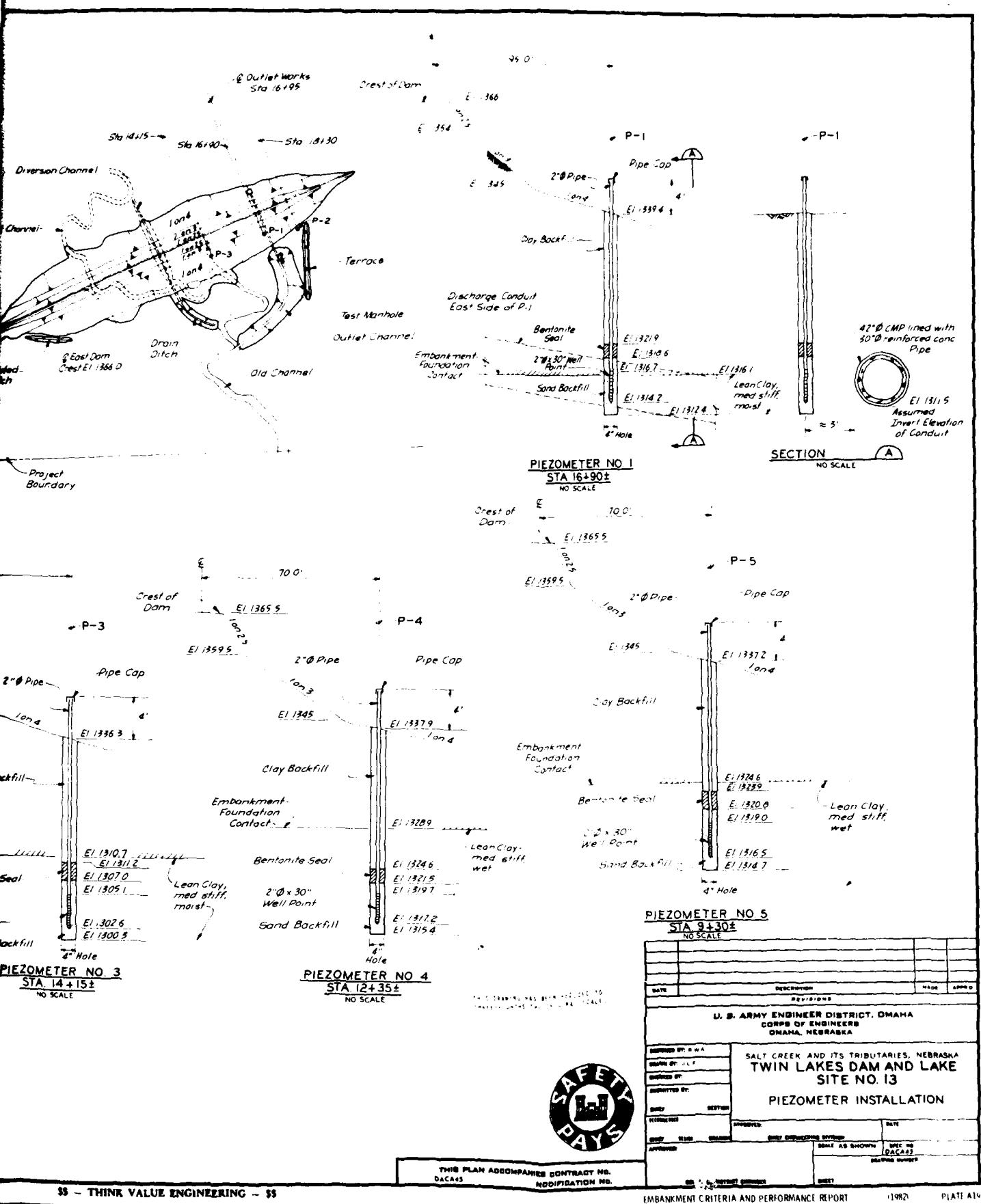
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			REVISIONS
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
DESIGNED BY: L. G. S.	SALT CREEK AND ITS TRIBUTARIES, NEBRASKA		
DESIGNED BY: P. J. L.	DAM AND RESERVOIR, SITE 13		
DESIGNED BY: D. C. C.	STABILITY ANALYSIS, CONSOLIDATION		
DESIGNED BY: C. L. L.	TESTS AND RIPRAP GRADATION		
APPROVED: Charles L. Lippman	DATE: APR 1982		
APPROVED: Donald E. DePauw	TITLE: ENGR. & TEST. SUPERVISOR		
APPROVED: Donald E. DePauw	GRADE: 1000		
APPROVED: Donald E. DePauw	SIGNATURE		

THIS PLAN ACCOMPANIES CONTRACT NO.
DA-39-088-
MODIFICATION NO.



2

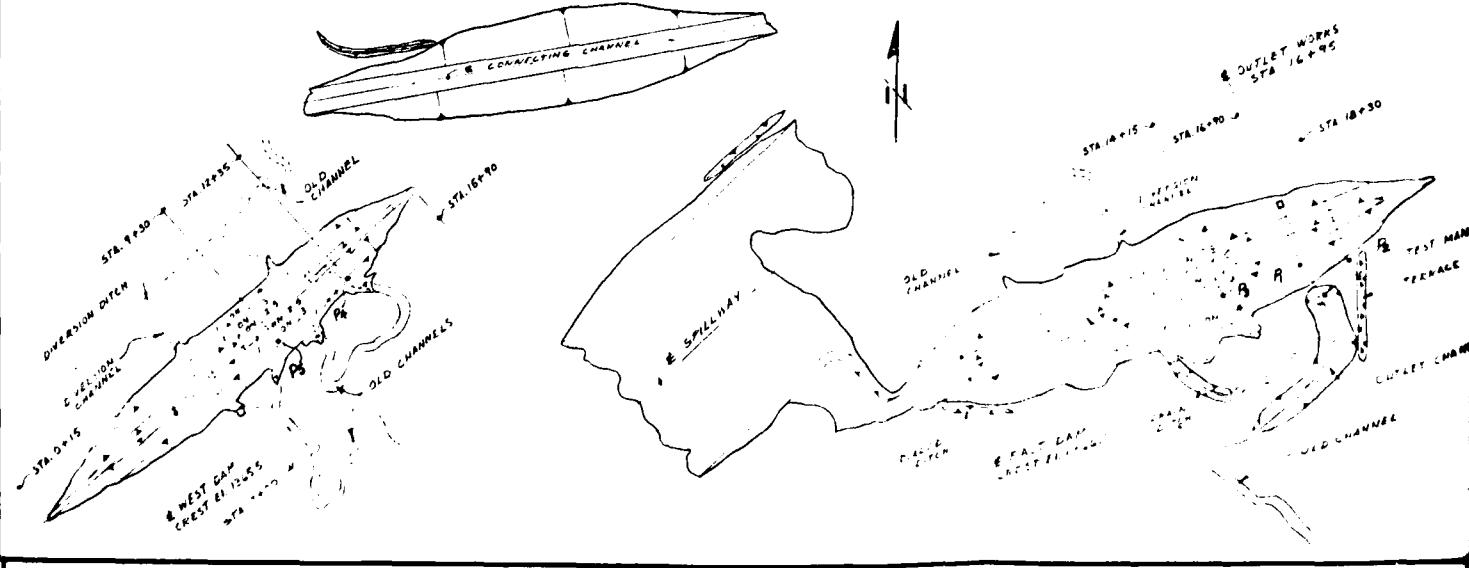
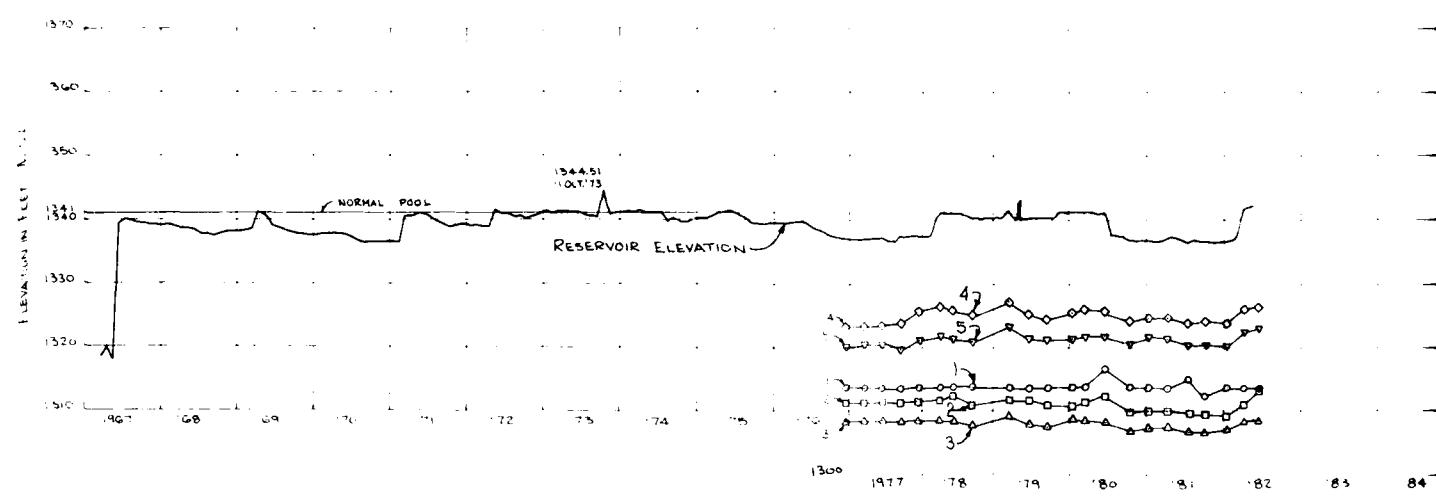
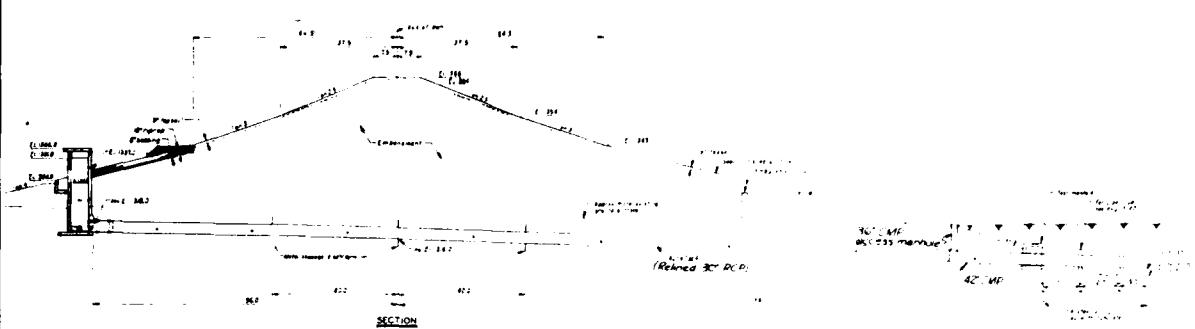


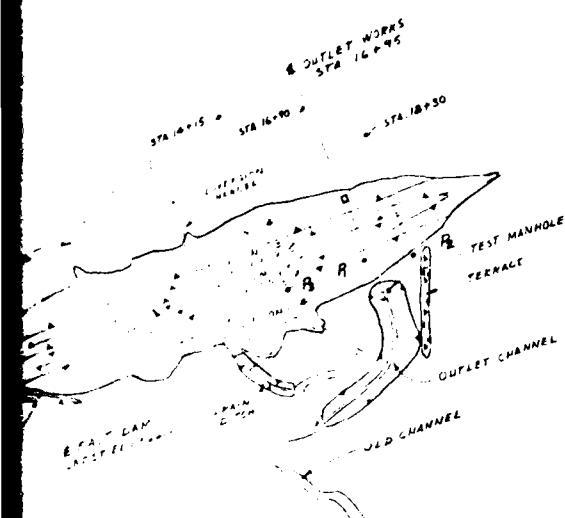
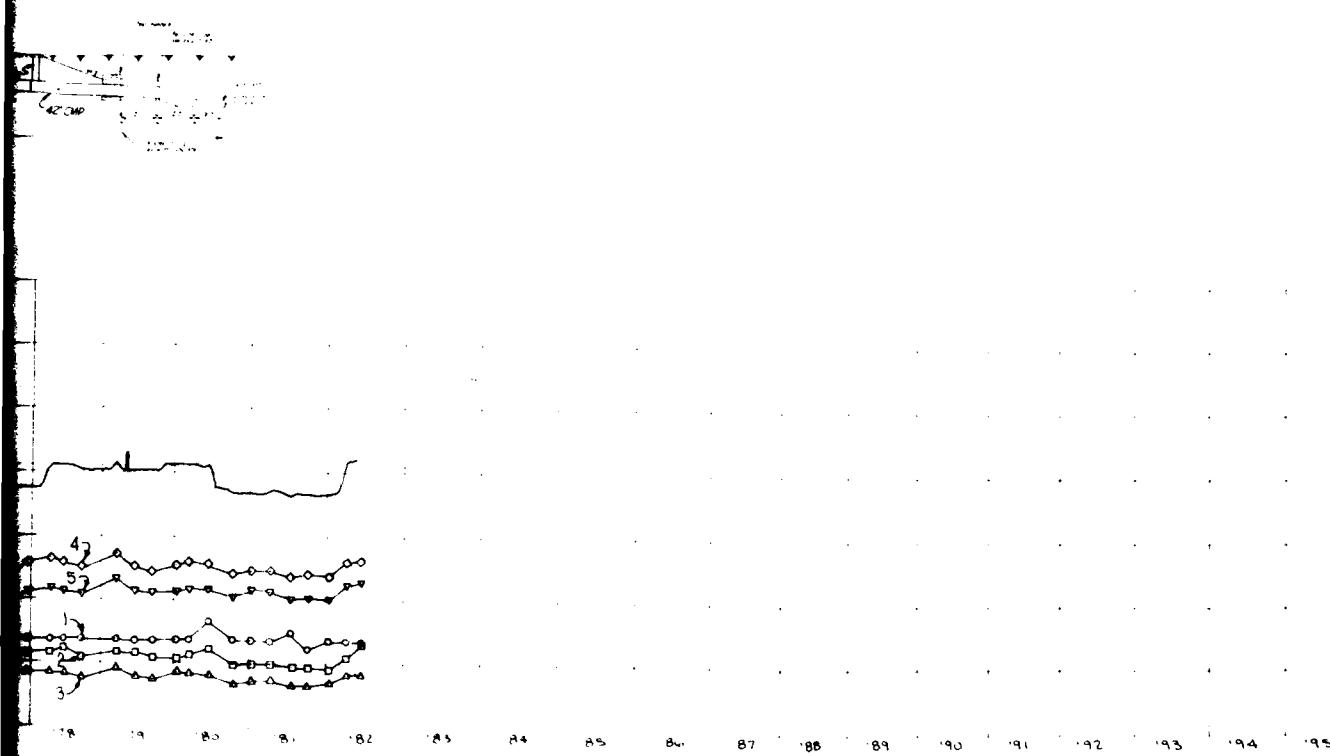


33 - THINK VALUE ENGINEERING - 33

THIS PLAN ACCOMPANIES CONTRACT NO.
DACA45 MODIFICATION NO.

EMBANKMENT CRITERIA AND PERFORMANCE REPORT (1982) PLATE A10



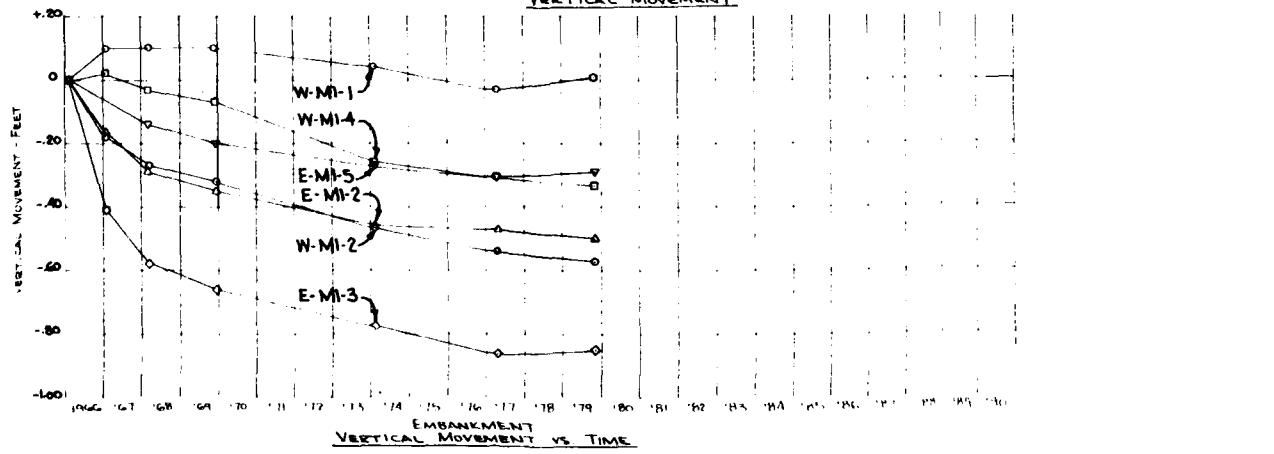
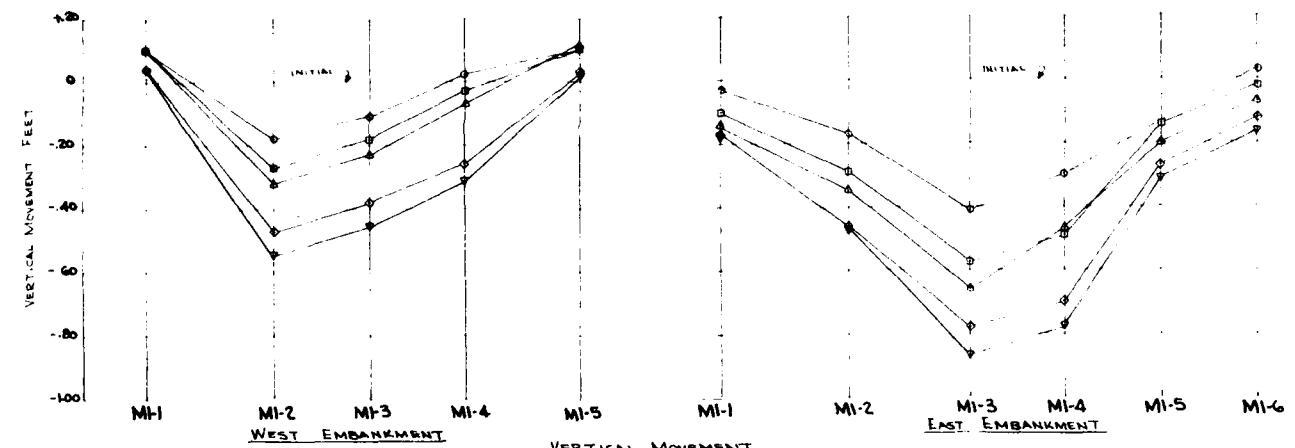
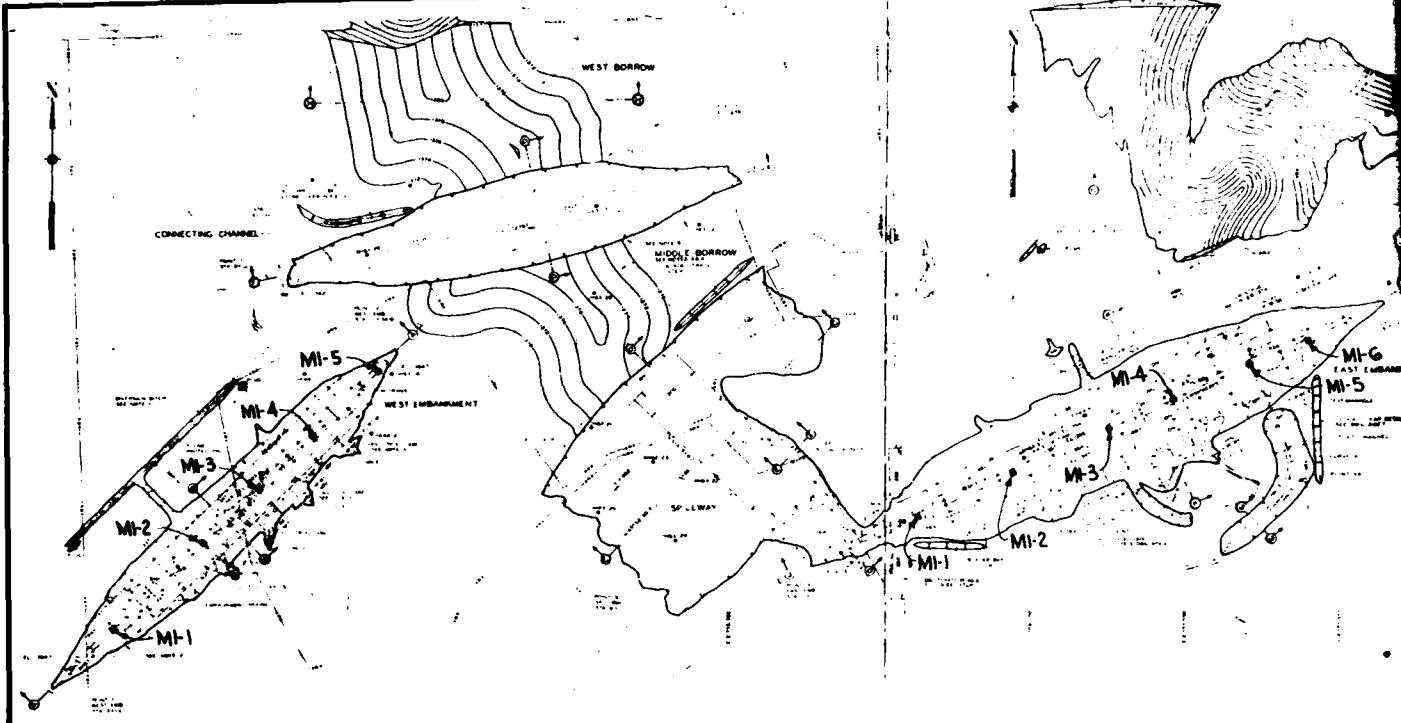


THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

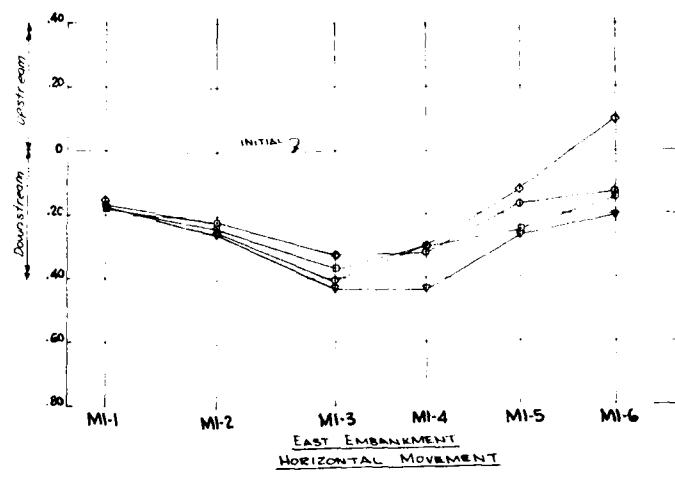
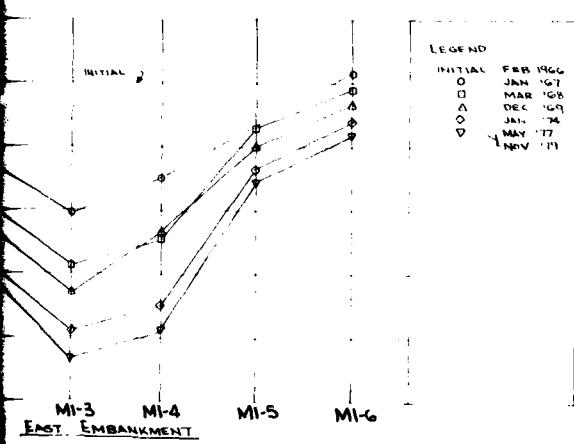
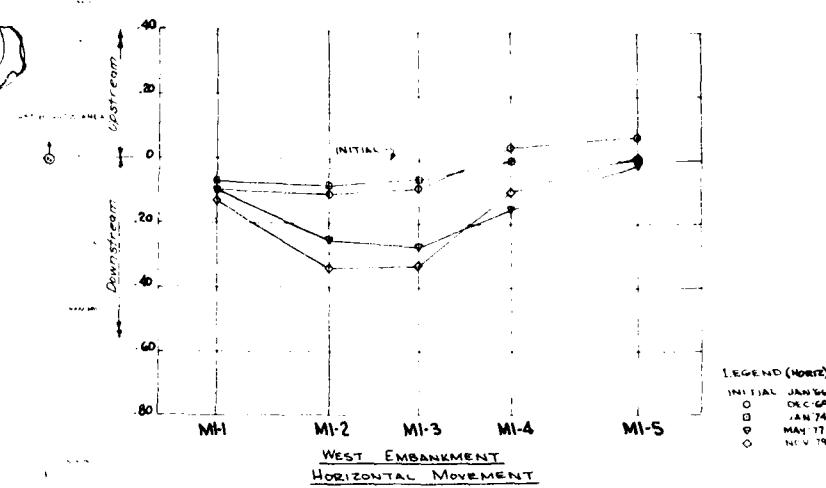
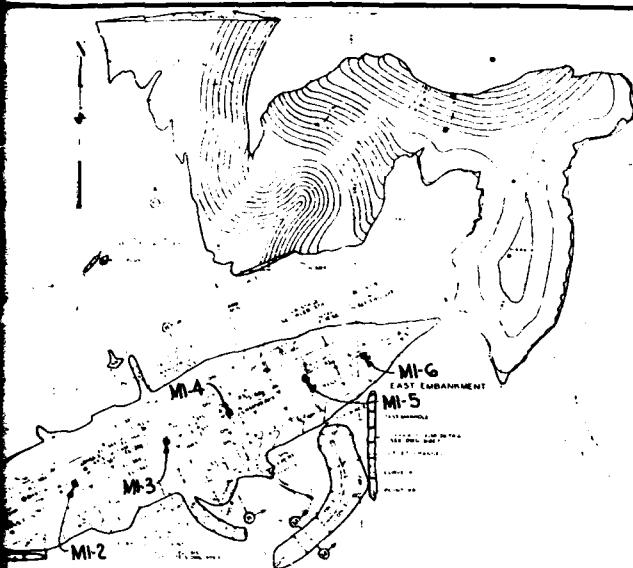


THIS DRAWING HAS BEEN REDUCED TO
THREE-EIGHTHS THE ORIGINAL SCALE.

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U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA					
DESIGNED BY:	SALT LAKE CITY, UTAH				
DESIGN BY:	SITE 13				
CHECKED BY:	TWIN LAKES DAM				
SUPERINTENDED BY:	RESERVOIR ELEVATIONS AND PIEZOMETER OBSERVATIONS				
APPROVED BY:	CHIEF ENGINEERING OFFICER		DATE		
APPROVED BY:	GRADE		SCALE AS SHOWN		SPEC. NO.
APPROVED BY:					DRAWING NUMBER
U. S. ARMY ENGINEER DISTRICT, OMAHA					
EMBANKMENT CRITERIA AND PERFORMANCE REPORT					
1982 PLATE A20					



EMBANKMENT VERTICAL MOVEMENT VS TIME



THIS DRAWING HAS BEEN REDUCED TO
THREE-FIFTHS THE ORIGINAL SCALE.

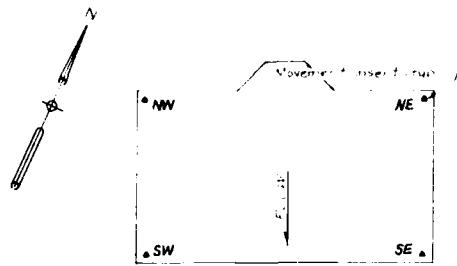
DATE	DESCRIPTION	NAME	APPROVED
	REVISIONS		
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
PREPARED BY:	SALT CREEK, NEBRASKA		
PROVED BY:	SITE 13		
DESIGNED BY:	TWIN LAKES DAM		
INVESTIGATED BY:	EMBANKMENT MOVEMENT INSETS		
REQD.	APPROVED	HORIZONTAL AND VERTICAL MOVEMENT	
REVIEWED	REVIEWED	NOV 1979	
INITIAL APPROVAL	INITIAL APPROVAL	NOV 1979	
APPROVER	APPROVER	NOV 1979	
REISSUED NOV 1979			



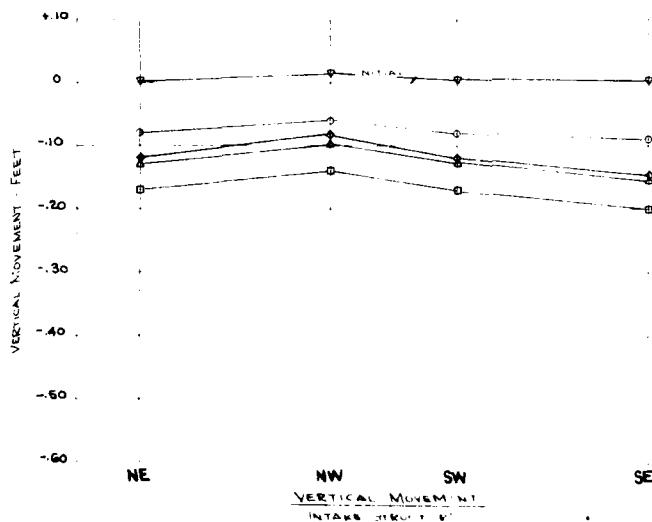
2
THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

EMBANKMENT CRITERIA AND PERFORMANCE REPORT

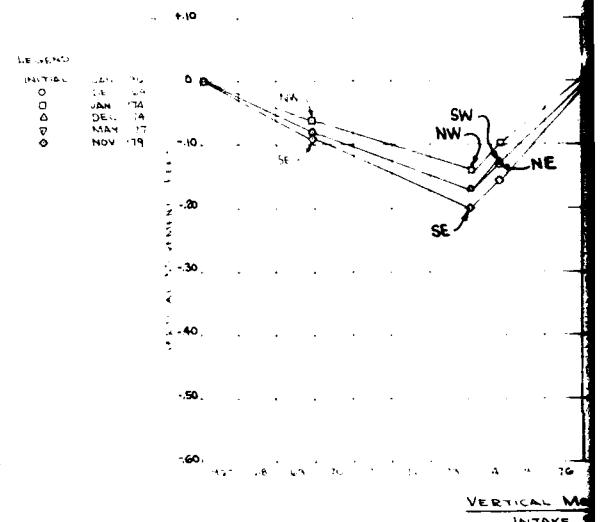
ONE PAGE ONE



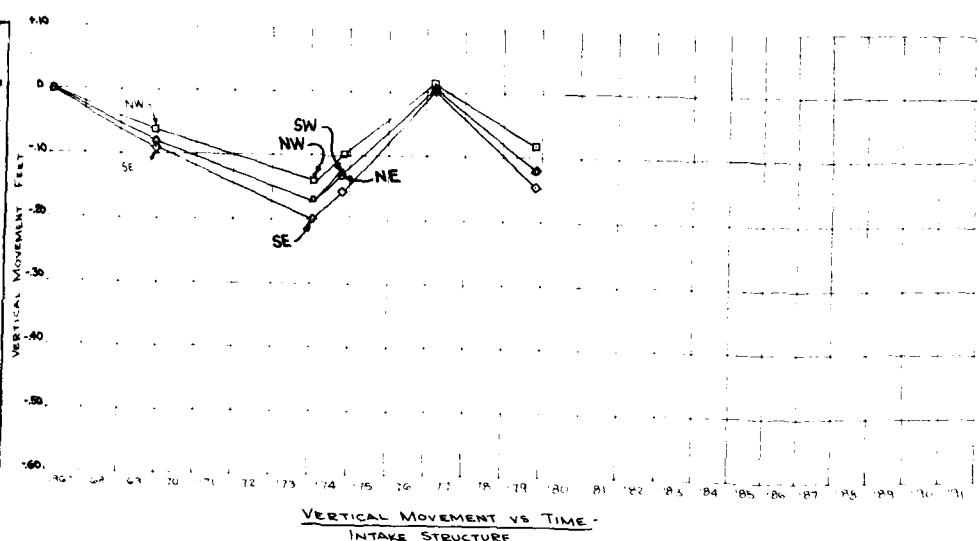
MAKE STRUCTURE PLAN



VERTICAL MOVEMENT
INTAKE 12KU 1/4"



VERTICAL MOVEMENT
INTAKE 12KU 1/4"



THIS DRAWING HAS BEEN REDUCED TO
ONE-EIGHTH THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPROVED
REVISIONS			
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
DESIGNED BY:	SALT CITY, NEBRASKA SITE 13 TWIN LAKES DAM		
DRAWN BY:	INTAKE STRUCTURE - VERTICAL MOVEMENT		
CHECKED BY:			
SUPERVISED BY:			
APPROVED BY:	CHIEF ENGINEER APPROVED	DATE:	
APPROVED BY:	SCALE AS SHOWN	SPCS 26	
APPROVED BY:	PACIFIC NORTHWEST		
APPROVED BY:	SHEET		

2
THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

U. S. ARMY ENGINEER DISTRICT

EMBANKMENT CRITERIA AND PERFORMANCE REPORT 11982 PLATE A22

APPENDIX B
PHOTOS



N

SALT CREEK AND ITS TRIBUTARIES, NEBRASKA
TWIN LAKES DAM AND LAKE
SITE NO.13

AERIAL PHOTOGRAPH

2

PLATE B1



Photo No. 2 - View of east embankment from left abutment. (Oct. 1979)

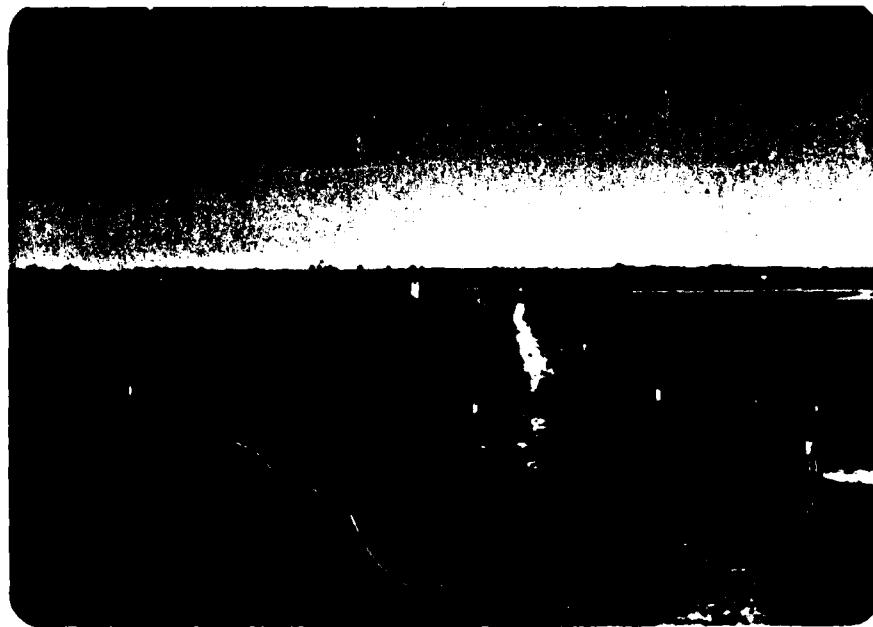


Photo No. 3 - View of upstream slope of the east embankment from the left abutment. (Oct. 1979)



Photo No. 4 - View of east embankment downstream slope from left abutment. (Oct. 1979)



Photo No. 5 - Riprap with access berm on east embankment. Intake structu. in background and water stage recorder housing at upper right. (Oct. 1979)



Photo No. 6 - View of west embankment from left abutment. (Oct. 1979)

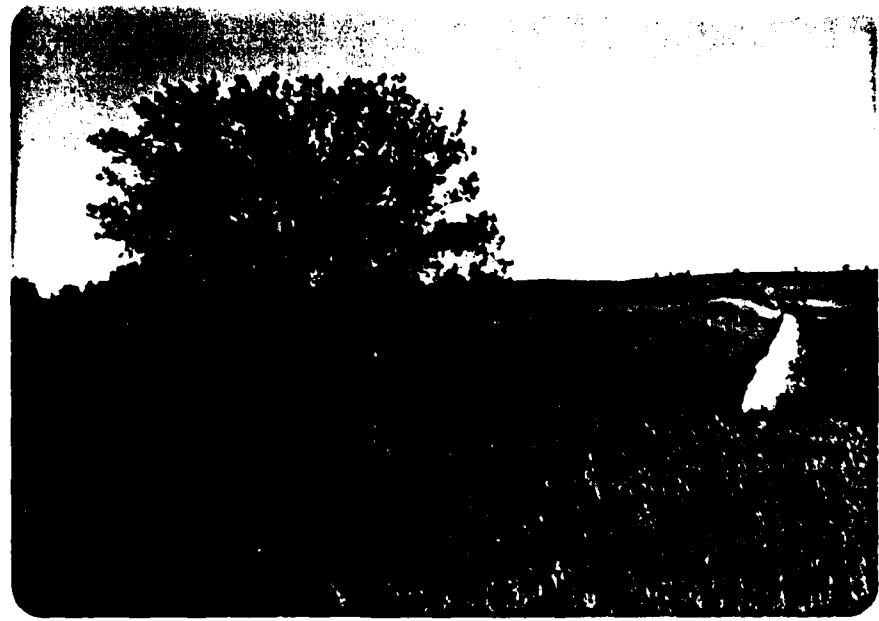


Photo No. 7 - Upstream slope of west embankment from the left abutment. (Oct. 1979)

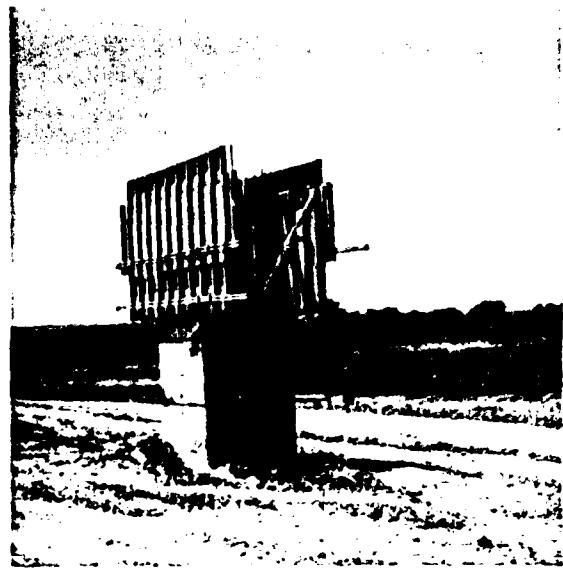


Photo No. 8 - View of intake structure at east embankment during construction with forms in place. (June 1965)

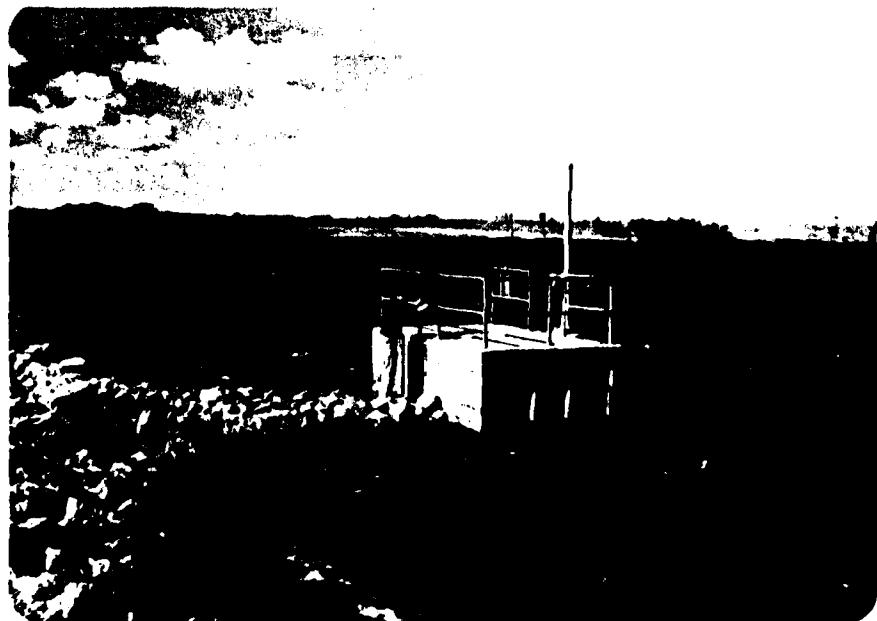


Photo No. 9 - Intake structure at east embankment.
(Oct. 1979)



Photo No. 10 - View of discharge conduit and discharge channel during construction. Intake structure is in background. (June 1965)



Photo No. II - View of outlet end of discharge conduit and plunge pool of east dam. Note erosion along right side of plunge pool. (Oct. 1979)



Photo No. 12 - Pumping grout through grout holes in annular space between new concrete lining and c. m. p. discharge conduit.



Photo No. 13 - View of a typical discharge conduit after concrete lining had been installed.